Mailed from Baltimore
November 19, 1958

Journal

OF THE

ELISHA MITCHELL Scientific Society

VOL. 74, NO. 2 NOVEMBER 1958

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Published for the Society by
THE UNIVERSITY OF NORTH CAROLINA PRESS *at* CHAPEL HILL

The Elisha Mitchell Scientific Society

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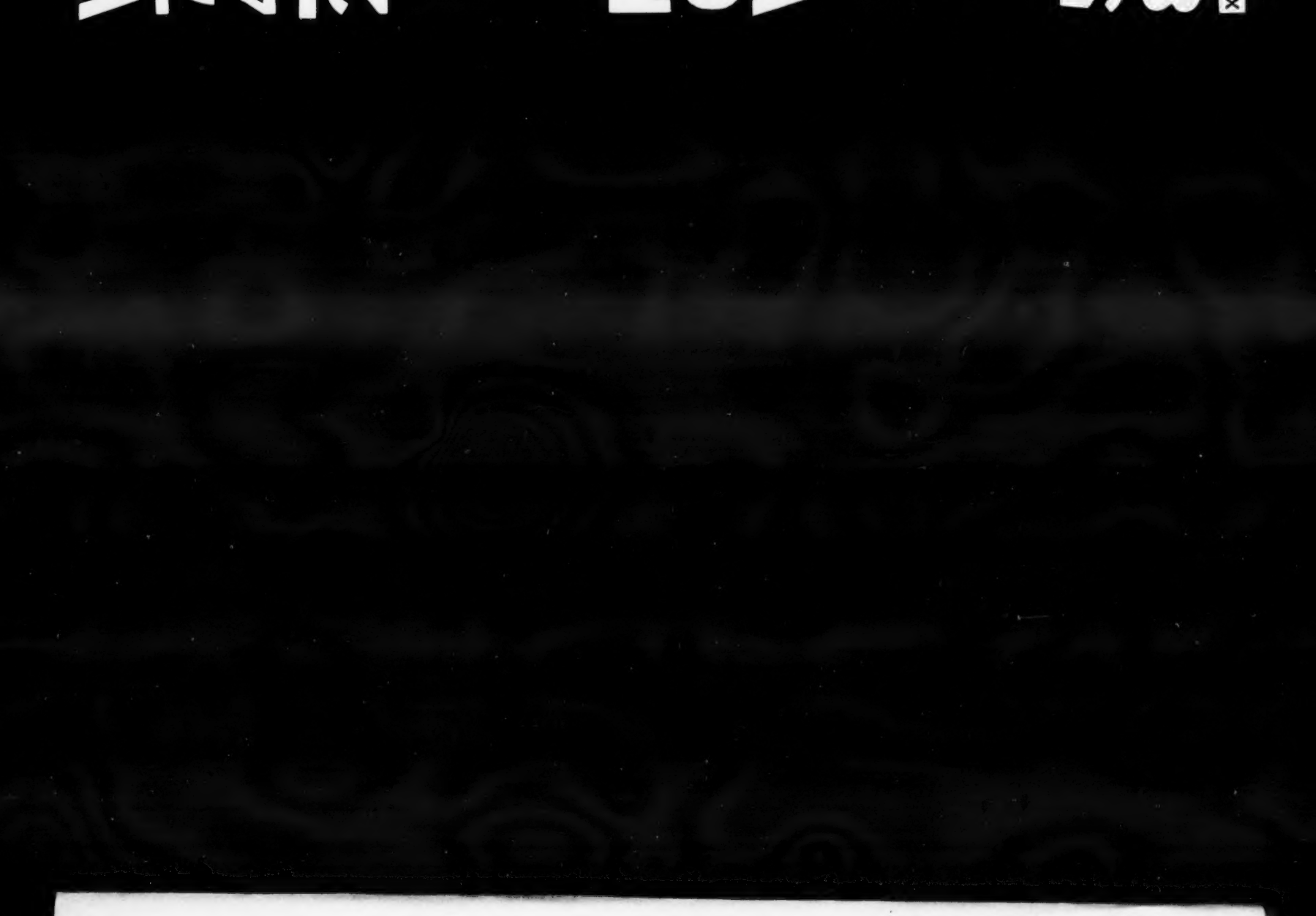
JOURNAL OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY—Semi-annual. Price $3.50 per year; single numbers, $1.75. Direct all correspondence to the Corresponding Secretary, at the University of North Carolina, Chapel Hill, N. C.

In addition to original papers on scientific subjects, this Journal publishes the Proceedings of the Elisha Mitchell Scientific Society, and the Proceedings of the North Carolina Academy of Science, including some abstracts of papers on scientific subjects published elsewhere.

PUBLISHED FOR THE SOCIETY
BY THE
UNIVERSITY OF NORTH CAROLINA PRESS

Made in the United States of America



JOURNAL
OF THE
Elisha Mitchell Scientific Society

Volume 74 November 1958 No. 2

PROCEEDINGS OF THE FIFTY-FIFTH ANNUAL MEETING OF THE NORTH CAROLINA ACADEMY OF SCIENCE

The fifty-fifth annual meeting of the North Carolina Academy of Science was held at Duke University, Durham, on May 2 and 3, 1958.

The Academy met in its first session at 10:00 a.m. on May 2 with President Berry presiding. A general session of three invited papers was held on this occasion.

The business meeting of the Academy was held at 4:30 p.m. on May 2, at which time the following business was transacted:

The minutes of the 1957 meeting were approved as published in the Journal of the Elisha Mitchell Scientific Society **73:** 214–246.

Report of the Executive Committee

The Executive Committee met at the home of President Berry in Durham on May 1 at 7:45 p.m. At this meeting the following matters were considered:

1. All persons who had applied for membership to this date were declared elected to membership. Names of new members appear later in these Proceedings.
2. Three persons were elected to Life Membership. These are J. C. Andrews of the University of North Carolina, C. F. Korstian of Duke University, and T. B. Mitchell of North Carolina State College.
3. The Committee voted to increase the contribution of the N. C. Academy to the Academy Conference from $5 per year to $10 per year. This increase has been requested by the Academy Conference.
4. The Committee brought to the Academy an amendment to the constitution as follows: Article II, Section 1, (d) Sustaining Members. Institutions, organizations, or industrial concerns may be elected as sustaining members by the Executive Committee upon the payment of a fee of $100 or more annually. All funds collected from this source will be used for the advancement of science in N. C. in such ways as the Executive Committee of the Academy may direct.

   Article II, Section 1, (e) Patron Members. Any person contributing a sum of $10 or more annually to the Academy may be elected by the Executive Committee as a Patron. All funds collected from this source will be used for the advancement of science in N. C. in such ways as the Executive Committee of the Academy may direct.
5. The Committee voted to accept the invitation of Catawba College to have the Academy meet on its campus in 1959.
6. The Committee voted to ask President Berry to serve during the remainder of 1958 in an active role as Past President seeking additional sustaining and patron members for the Academy.
7. At several of its meetings the Committee discussed the preparation of a history of the N. C. Academy of Science. Furtherance of this project awaits the designation of a person to lead in its preparation. The Committee will welcome suggestions from the membership in this matter.
8. John A. Yarbrough was named to represent the Academy at the AAAS in Washington, December 1958, and also at the Academy Conference at the same time. The incoming President and Secretary-Treasurer were empowered to name another member of the Academy as a second representative to the Academy Conference.
9. The Committee voted to ask the Academy to approve the election of twenty-five high school students as junior members of the Academy. Ten of these are winners at the State Science Fair in 1958 as follows:

   Nancy Green, Enka High School, Candler
   Roy T. Eddleman, Kannapolis High School, Kannapolis
   Robert Miller, Chapel Hill High School, Chapel Hill
   Rodney McCurrie, Enka High School, Candler
   Yvonne Walker, Hayesville High School, Hayesville

Frank C. Ziglar, Needham Broughton High School, Raleigh
George Cannon, Farmville High School, Farmville
Rufus R. Russell, Greensboro High School, Greensboro
James Sawers, Greensboro High School, Greensboro
T. D. Phillips, Jr., Morehead City High School, Morehead City

Fifteen were named for honors in the 1958 N. C. State Science Talent Search as follows:

Alton Tripp, Jr., Needham Broughton High School, Raleigh
Russell Honeycutt, Central High School, Mooresville
Maurice V. Barnhill, III, New Hanover High School, Wilmington
James R. Sawers, Greensboro High School, Greensboro
Karen Lynne Conklin, Walkerton High School, Kernersville
Susan Beatty, Needham Broughton High School, Raleigh
Rufus R. Russell, Greensboro High School, Greensboro
Noah M. Hicks, Shelby High School, Shelby
Roy T. Eddleman, A. L. Brown High School, Kannapolis
Ian Morgan Happer, Lenoir High School, Lenoir
William Stuart Hurt, Needham Broughton High School, Raleigh
Robert E. Sevier, Lee Edwards High School, Asheville
Maryland Rodney Midgett, Dixon High School, Sneads Ferry
Wayne E. Pennell, A. L. Brown High School, Kannapolis
Charles R. Philbrick, Cary High School, Cary

10. The following were elected to membership in the Academy or reinstated to active membership:

Barker, Dr. June N., Duke University School of Medicine, Durham
Bell, Thomas A., N. C. State College, Raleigh
Boyette, Joseph Greene, East Carolina College, Greenville
Carter, William G., Duke University, Durham
Conley, James Franklin, N. C. Department of Conservation and Development, Raleigh
Conrad, Stephen G., Division of Mineral Resources, Raleigh
Coots, Dr. Alonzo Freeman, N. C. State College, Raleigh
Cosby, Bertram O., Salem College, Winston-Salem
Davis, David Gale, University of N. C., Chapel Hill
Dunton, Rupert C., Warren Wilson College, Swannanoa
Eckhoff, Oscar Bradley, University of N. C., Chapel Hill
Edmisten, Joe Allen, University of N. C., Chapel Hill
Edwards, Dr. Gerald A., A. & T. College, Greensboro
Eliason, Miss Nancy Blair, Averett College, Danville, Virginia
Epperson, Edward Roy, Elon College, Elon College, N. C.
Flowers, John Morgan, Jr., Duke University, Durham
Fluke, Dr. Donald J., Duke University, Durham
Frayser, Miss Regina, Duke Medical Center, Durham
Fridovich, Dr. Irwin, Duke Hospital, Durham
Gardner, M. E., N. C. State College, Raleigh
Glockler, Dr. George, Duke University, Durham
Harmon, Miss Elizabeth Anne, Duke University, Durham
Haubrich, Dr. Robert Rice, East Carolina College, Greenville
Heath, George A., Collins & Aikman Corp., Roxboro
Hill, Dr. Douglas G., Duke University, Durham
Hirschmann, Dr. Hedwig, N. C. State College, Raleigh
Honeycutt, Mrs. Peggie H., N. C. State College, Raleigh
Horton, Frank N., Central High School, Charlotte
Horton, James Heathman, University of N. C., Chapel Hill
Howe, Dr. Henry Branch, Jr., Wake Forest College, Winston-Salem
Humm, Dr. Douglas G., University of N. C., Chapel Hill
James, William Stuart, University of N. C., Chapel Hill
Johnson, Dr. J. Robert, Jr., Wake Forest College, Winston-Salem
Johnson, J. Stanley, Greensboro High School, Greensboro
Johnston, Dr. Charles L., Jr., University of N. C. School of Medicine, Chapel Hill
Jones, Hubert A., Wake Forest College, Winston-Salem
Kersey, R. L., Jr., Liggett & Myers Tobacco Co., Durham

Knight, Dr. Clifford Burnham, Jr., East Carolina College, Greenville
LeConte, Dr. Joseph Nisbet, East Carolina College, Greenville
Levine, Dr. Jack, N. C. State College, Raleigh
Lucas, Dr. G. B., N. C. State College, Raleigh
Mac Nerney, Dr. J. S., University of N. C., Chapel Hill
Markham, Dr. E. C., University of N. C., Chapel Hill
Marshall, Dr. Norman B., Duke University Medical Center, Durham
Mayer, Thomas C., Greensboro College, Greensboro
McAllister, Harmon Carlyle, N. C. Board of Pharmacy, Chapel Hill
McDearman, Miss Ella Battle, Needham Broughton High School, Raleigh
McGavran, Dr. E. G., University of N. C., Chapel Hill
Meetze, G. C., Jr., Davidson College, Davidson
Mewborn, Ancel Clyde, University of N. C., Chapel Hill
Miller, Dr. Bradford, University of N. C., Chapel Hill
Miller, Dr. Grover C., N. C. State College, Raleigh
Newman, Dr. Slater E., N. C. State College, Raleigh
Oliver, George Motley, N. C. State College, Raleigh
Paulson, Jehu D., N. C. State College, Raleigh
Pettis, Dr. Billy James, University of N. C., Chapel Hill
Pike, Dr. Frederick Philips, N. C. State College, Raleigh
Quin, Dr. Louis D., Duke University, Durham
Read, Floyd M., Jr., East Carolina College, Greenville
Reagan, Mrs. W. F., Chapel Hill High School, Chapel Hill
Rohrbach, Dr. Hans J., University, of N. C., Chapel Hill
Ruth, John Moore, Kinston
Salzano, Dr. John V., Duke University Medical Center, Durham
Santolucito, Dr. John A., N. C. State College, Raleigh
Schramm, Robert J., Jr., N. C. State College, Raleigh
Seery, Miss Virginia Lee, Duke University, Durham
Shaw, Aubrey M., Harrells, N. C.
Shipton, Clarence, Curry High School, Greensboro
Sinha, Evelyn Z., University of N. C., Chapel Hill
Snipes, Charles A., Duke Hospital, Durham
Speece, Dr. Herbert E., N. C. State College, Raleigh
Spencer, Dr. Merrill O., Bowman Gray School of Medicine, Winston-Salem
St. Jean, Dr. Joseph, Jr., University of N. C., Chapel Hill
Sumner, Dr. George Kendrick, University of N. C., School of Medicine, Chapel Hill
Terrell, Dr. Edward E., Guilford College, Guilford College
Todd, Daniel E., Jr., New Hanover High School, Wilmington
Totton, Dr. Ezra L., North Carolina College, Durham
Vermillion, Dr. Gertrude, Woman's College of U. N. C., Greensboro
Waddell, Dr. William Joseph, University of N. C. Medical School, Chapel Hill
Wadsworth, James Edgar, University of N. C., Chapel Hill
Wall, Dr. Drury William, University of N. C., Chapel Hill
Ward, Dr. Calvin L., Duke University, Durham
Wells, William Tunstall, N. C. State College, Raleigh
Willis, David C., N. C. State College, Raleigh
Winton, Dr. Lowell S., N. C. State College, Raleigh
Zobel, Dr. Bruce J., N. C. State College, Raleigh

Patron Members as of February 19, 1958

Governor Luther H. Hodges, Raleigh
W. Y. Preyer, Greensboro
C. M. Goethe, Sacramento, California
Richard E. Thigpen, Charlotte
Harold D. Cooley, House of Representatives, Washington, D. C.
Justice Emery B. Denny, Raleigh
Mrs. Inglis Fletcher, Edenton
Reuben B. Robertson, Asheville
C. P. Street, Charlotte
Irving E. Carlyle, Winston-Salem
Edward R. Zane, Greensboro
Norman A. Cocke, Charlotte
Mrs. Courtenay Anderson, Hendersonville
Burnham S. Colburn, Asheville

Sustaining Members as of February 19, 1958

Block-Southland Sportswear, Inc., Wilmington
E. I. du Pont de Nemours & Company, Kinston
Roxboro Cotton Mills, Roxboro
The Dickson Foundation, Inc., Mount Holly

Liggett & Myers Tobacco Company, Durham
Celanese Corporation of America, Charlotte
Sovelco Mills, Inc., Fall River, Massachusetts

The above reports and actions of the Committee were approved by the Academy in its business session on May 2, 1958.

TREASURER'S REPORT

Financial Statement as of July 1, 1958

Receipts—Academy proper		
Checking account adjusted balance on July 1, 1957 (Security National Bank, Raleigh)	$543.41	
Dues from memberships (regular)	1545.00	
Dues from patron members	240.00	
Dues from sustaining members	700.00	
Collegiate Academy gifts	125.00	
Collegiate funds deposited	39.00	
N. C. Psychological Association, for programs	3.75	
American Chemical Society, N. C. Section, for programs	9.00	
Derieux prize	50.00	
Exhibit fees, commercial	30.00	
AAAS for trip to Washington by Secretary-Treasurer	75.00	
Total Receipts Academy proper		$3360.16
Receipts—Science Fair Program		
Entry fees from seven districts	$1350.00	
Medical Society of North Carolina	100.00	
American Chemical Society, N. C. Section	75.00	
Carolina Power and Light Company	175.00	
Southern School Supply Company	125.00	
Cardinal Products, Inc.	100.00	
Carolina Biological Supply Company	50.00	
J. D. Taylor for Denoyer-Geoppert Company	50.00	
Return on National Fair Expense	15.35	
Total receipts for Science Fair Program		$2040.35
Total Receipts for Academy and Science Fairs		$5400.51
Expenditures—Academy proper		
Derieux Memorial Award—to Collegiate Academy	$50.00	
Research Grants	350.00	
Cancas, Collegiate Journal, two issues	124.25	
Postage, Stationery, Office Supplies	303.58	
Expenses of Annual meeting, 1958	143.81	
Printing	187.80	
Bank charges	.38	
Secretarial Aid	80.10	
Secretary's commission for 1956–57 balance	45.20	
Secretary's commission for 1957–58	68.60	
Secretary's travel expense	44.70	
Telephone (long distance calls)	46.11	
Reprints of 1957 Proceedings	7.00	
Expense for representation to AAAS Convention, 1957	50.00	
Expense for Washington trip, Academy Conference, Secretary	75.00	
Fidelity Bond (3 yr) for Treasurer	12.50	
Elisha Mitchell Scientific Society	558.50	
Academy Conference	5.00	
Total Expenditures for Academy proper		$2152.53
Expenditures—Science Fair Program		
Medals from Science Service, Washington	$ 31.50	
Announcement brochures, 1958 Fairs	125.00	
Pictures made of exhibits at 1958 State Science Fair	22.50	
Entrance Fee, National Science Fair	175.00	
To Duke University for 1958 State Science Fair Expense	200.00	
Expense for National Fair party, four persons, at Flint, Mich.	624.67	
Prizes at State Science Fair	220.00	
Luncheon for planning 1959 Science Fairs	38.47	
Travel for persons attending above luncheon	68.74	
Certificates for Science Fairs	50.73	
Total Expenditures Science Fair Program		$1556.61
Total Expenditures for Academy and Science Fairs		$3709.14
Bank balance as of July 1, 1958	$2362.53	
Plus deposits not shown	38.00	
	$2400.53	
Less outstanding checks	709.16	
Adjusted bank balance	$1691.37	1691.37
Total to account for		$5400.51

Total Assets

Checking account (adjusted)	$1691.37
Savings Account, Security National Bank	8.78
Raleigh Savings and Loan Account as of July 1, 1958	339.59
Total	$2039.74

On the 12th of July, 1958, we, the undersigned, examined this account and found it to be correct.

(Signed) F. H. SMITH, *Chairman*
F. S. BARKALOW, JR.
DANIEL T. POPE

THE POTEAT AWARD

The award for this year was given to the best paper presented before the Botany Section. The award was won by E. C. Maine and Arthur Kelman of N. C. State College for their paper, "Possible mechanisms of resistance in solanaceous plants to *Pseudomonas solanacearum*". The certificate will be presented at the Academy banquet next year, 1959.

REPORT OF COMMITTEE ON RESEARCH GRANTS

The research funds of the Academy were greater at the beginning of this year than they have ever been before, and it is probable that we shall have as much available again next year. Consequently the committee was able to look with favor upon applications of members of the NCAS or of CANCAS for assistance on five different projects during its meeting on January 9, 1958. Investigations were made from the Haw River to the outer banks, and in fields as diverse as stream pollution and ornithology, crystal structure and embryology. The amounts granted ranged from $25 up to $150, and they totaled $350.

The present policies of the research grants committee are centered around giving aid to scientific investigations which cannot be undertaken without assistance or which can be done only with great difficulty or excessive expense not reimbursable elsewhere. To this end a clear statement of intention and methods is needed, and these statements must be circulated to each member of the research grants committee before decision. Sponsorship or endorsement of the application by a member professionally engaged in the field of research or in a neighboring field is helpful.

The recipient of a research grant is expected to make three reports, which may be combined into two. They are (1) a progress report to the chairman of the Committee on Research Grants before the date of the annual meeting, (2) an oral report to a section of the Academy in lieu of the above or at a later annual meeting, if appropriate, and (3) a financial account, itemized to a moderate extent, upon the completion of the project or the disbursement of all funds, whichever comes first.

We call your attention to the need for encouraging the inquiring mind and of suggesting that young students with ability be invited by you to apply for some of the research funds in the hands of the Academy.

MAURICE WHITTINGHILL

REPORT OF THE CONSERVATION-LEGISLATIVE COMMITTEE

The Conservation-Legislative Committee did not meet during the past year, but continuous contact with national legislation affecting various phases of conservation was maintained through reports, such as the Conservation Report of the National Wildlife Institute.

Dr. Lowry contacted Nature Conservancy (4200 - 22nd Street, N. E., Washington, D. C.) to determine whether any land for "outdoor museum" purposes was being acquired, or considered for acquisition, in North Carolina by that organization at present, and the reply was in the negative.

Dr. Radford has proposed that steps be taken to acquire or set aside three areas of outstanding natural scientific interest in North Carolina, these areas being:

(1) The granite outcrop area at Mitchell's Mill near Rolesville (probably the only remaining unexploited granite outcrop in North Carolina).
(2) The eastern white pine (*Pinus strobus* L.) community at the confluence of Deep and Rocky Rivers in Chatham County.
(3) The eastern hemlock (*Tsuga canadensis* (L.) Carr.) community on Swift Creek near Cary.

This Committee recommends that the Academy take steps to determine the feasibility of acquiring (or dedicating within existing ownership) tracts of suitable size to preserve the "outdoor museum" aspects of these three areas.

The Committee Chairman has maintained liaison with the Committee on Natural Areas of the Society of American Foresters. The latter Committee has approved 82 parcels of land with minimum gross area in no instance less than 20 acres as suitable for Natural Area. These areas are located in 30 out of 48 States. The S. A. F. definition of Natural Areas is as follows: "An area set aside to preserve permanently in un-

modified condition (insofar as possible) a representative unit of the virgin growth of major forest types primarily for the purpose of scientific study, research and education. Timber cutting and grazing are prohibited, and general public (i.e., recreational) use discouraged."

It is recommended that the North Carolina Academy of Science join with Nature Conservancy, the Society of American Foresters, and local chapters of other interested organizations such as the Izaak Walton League to work toward the goal of preserving, through acquisition or other means, suitable natural areas or "outdoor museums" including the three listed above for study and enjoyment in North Carolina.

WANDA HUNTER
E. M. LOWRY
A. E. RADFORD
T. E. MAKI, *Chairman*

REPORT OF THE COLLEGIATE ACADEMY

During the year 1957–58 the Collegiate Academy held two meetings. The first was a meeting of the executive committee on October 12, 1957, at Meredith College, at which time plans for the year were discussed. The following colleges were represented: Atlantic Christian, Duke, Greensboro, Meredith, Pfeiffer, and Woman's College. It was decided that for this year, at least, we would leave field trips to the individual clubs and concentrate our activities on the lectureships and the annual meeting.

Dr. T. W. Johnson, Jr., who is in charge of the lectureship program, reported in May that only 22 lectures were asked for this year, which is fewer than last year.

Two issues of Cancas were published, one in late November, and one in April. They contained the prize-winning paper from last May's meeting, abstracts of several others, letters from Dr. Vernberg from Jamaica, and from Dr. Le Vesconte about her year in Pakistan, notices of research funds, both those which are available and those which have been allotted, and the notice and information about the annual meeting.

The annual meeting was held on Friday, May 2, 1958, at Duke, as part of the N. C. Academy of Science meetings. A social hour at 11:30 was followed by a luncheon at which Dean Marcus Hobbs of the Graduate School, Duke University, spoke on "The Education of a Scientist". The main meeting was at 2:00 at which time seven papers were given. It was well attended by both faculty and students, there being no other section meeting that afternoon. After the program a short business meeting was held, officers for the next year were elected and the Derieux award for the best paper was announced. It went to Richard C. Stone, of Duke University, for his paper "The toxicity of some basic proteins tested in mice". Arrangements for the meeting were made by Henry Tschinkel, president, under the direction of Dr. T. W. Johnson, Jr.

The total membership this year is 41 individual and 7 club memberships, representing the following colleges: Appalachian, Atlantic Christian, Barber-Scotia, Belmont-Abbey, Duke, East Carolina, Flora Macdonald, Greensboro, Guilford, Meredith, Pfeiffer, Queens, State College, Wake Forest, Western Carolina, and Woman's College. This is not only an increase in total membership over last year, but it also represents more colleges.

CHARLOTTE DAWLEY

NORTH CAROLINA SCIENCE FAIRS

This report will include only general statements concerning the operation of the Science Fair Program in North Carolina during the period, 1 July 1957 to the present date. At the end of the present scholastic year a full report will be prepared. This report will include statistics concerning participation, lists of winners, etc.

The Institute of Natural Science at the University of North Carolina agreed to become a cosponsor for the fair program starting the first of July. I was appointed State Director at that time, succeeding Dr. Hollis Rogers, of the Woman's College of the University of North Carolina, who had so successfully steered the program through its first three years of operation in this state. The office of the Institute of Natural Science has furnished clerical help during the year and has made possible more extensive operations in connection with the distribution of literature, liaison with the national offices at Washington, etc. A special letterhead was prepared and this has been used in connection with all official correspondence.

The same general program that has been followed in past years was followed during the present year. This included the holding of seven district fairs, the promotion of local school fairs, the holding of the state fair, and the sending of two winners to the national fair. Location of the district fairs with the names of the directors will be given in the final report. The director would

at this time like to express to the district directors his gratitude for their fine work in handling their individual fairs.

Participation in the district fairs showed a significant increase over the prior year, both in number of individual participants and in the number of schools entering participants. The exhibits in general were of a much higher quality, reflecting good work on the part of the local schools. While it cannot be proven from the statistics, the director is certain that a much higher participation in local school fairs characterized the present year.

Dr. Yarbrough has continued his fine work in obtaining sponsors to help with the finances of the program. Financially the fair program is in good shape but more money would certainly help bring about an expansion of the present operations. A financial report is given in this issue of the Journal of the Elisha Mitchell Scientific Society.

The supply of handbooks and manuals that has in the past been supplied by the Oak Ridge Institute of Nuclear Studies has now been exhausted. A manual for use in the program in this state will be prepared this coming summer and will be available for distribution to teachers this fall.

All indications point to an improved program for the scholastic year, 1958–59. Especially large fairs are expected in the North Piedmont District at Winston-Salem and in the South Piedmont District at Charlotte. The list of newspapers, industrial organizations, professional groups, and other organizations sponsoring the program in this state continues to grow. This is true not only in terms of the total number but also in terms of enthusiasm for the program. The director wishes to express to each his thanks for their fine support. A list of the individual sponsors will be included in the final report.

H. D. CROCKFORD

REPORT OF THE ACADEMY CONFERENCE

The 1957 meeting of the Academy Conference was held during the AAAS meetings in Indianapolis, Indiana, on December 28, 1957. John A. Yarbrough represented the N. C. Academy of Science. Thirty-five persons were present representing twenty-five member Academies and two guest Academies, Montana and Arizona. A business session during the morning period consisted of committee reports and summaries of activities from the various Academies. The feature of the afternoon session was a panel discussion on "Implementation of recommendations of the Chicago Conference on Junior Academies". The Chicago Conference had been held in February of 1957. Five speakers appeared on the panel. With some rewording of the original Chicago proposals, ten statements or proposals were agreed upon in the afternoon session by all Academy representatives present. These represent the Conference's suggestions toward the improvement of Junior Academies over the nation. A dinner meeting concluded the Conference sessions for 1957. The president, Mrs. Thelma Heatwole, presented the annual address. The immediate past-president, Father Patrich H. Yancey, S.J., presided during this last session. Dr. A. M. Winchester, Stetson University, Florida, was selected as the president-elect of the Conference for 1958. John A. Yarbrough will serve during this period as the president.

REPORT ON COUNCIL MEETINGS OF THE AAAS

Two meetings of the Council of the AAAS were held in Indianapolis on December 27 and 30, 1957. Announcement was made of the election of the following officers of the AAAS for 1958 by previous mail ballots: Paul E. Klopsteg as President-Elect and William W. Rubey, Thomas Park and Mina S. Rees as members of the Board of Directors. Dr. Paul B. Sears, Chairman of the Board of Directors, called attention to the successful merger of the magazines Science and Scientific Monthly into one publication called "Science". A financial report indicated that the year 1957 would probably be ended with an approximate balance rather than the $40,000 deficit which had been expected earlier. Membership in the AAAS has increased by about 3,300 during the past year. New affiliates approved include the Chicago Academy of Sciences, the Rochester Academy of Science and the Montana Academy of Sciences.

Three of the resolutions adopted by the Council will be of interest to the members of our Academy: (1) a resolution to be sent to the Academy of Sciences of the Union of Socialist Soviet Republics as follows, "The American Association for the Advancement of Science, convened in Indianapolis, Indiana, in its annual meeting, sends greetings to its fellow scientists in the Soviet Union and congratulates them upon their scientific and technological achievements, including those manifested in the launching of earth satelites." (2) a resolution "that the Coun-

cil of the AAAS approves in principle the general adoption of the metric system of weights and measures. It tenders its cooperation to the British Association in any practicable efforts to further this objective." (3) a resolution calling for the AAAS to convene as soon as possible a Parliament of Science for the purpose of recommending action in this field to the Congress of the United States. Such a meeting was held in Washington, D. C. on March 15–17, 1958 at which approximately 125 persons attended as official representatives. John A. Yarbrough represented the N. C. Academy at both Council sessions.

Report of the Resolutions Committee

Be it resolved that the North Carolina Academy of Science express its appreciation to President Edens and his administrative assistants, to the faculty and to the students of Duke University for their cordial hospitality at this, the 55th annual meeting of the Academy. To the chairman and members of the local committee and to the numerous persons who have cooperated with them we are grateful for the foresight and diligent efforts which have made this meeting proceed smoothly and comfortably in most pleasant surroundings.

Be it further resolved that a copy of this resolution be incorporated into the minutes of the Academy for 1958 and that copies be sent to President Edens and to the chairman of the Committee on Arrangements at Duke University.

Ben H. Hill

The above resolution was unanimously approved by the Academy.

Memorials were read to the following members: John Paul Givler, Leon Franklin Williams, John Oliver Halverson, James W. Moffitt, and Velma Dare Matthews. The memorials were approved by a rising vote of the members.

John Paul Givler

John Paul Givler, Professor Emeritus of Biology at the Woman's College of the University of North Carolina, died in Greensboro June 10, 1957, after suffering a heart attack a few days previously. Professor Givler was born in Paola, Kansas, August 4, 1882, son of Henry Y. and Ann Elizabeth (Good) Givler. The father was a Methodist minister, and, as is usual with Methodist ministers, he was assigned to pastorates ranging geographically from Olean, New York, to Tacoma, Washington. In Washington, the son attended Tacoma High School and Puget Sound University. Then his father was transferred to St. Paul, Minnesota, where young John Paul entered Hamline University, and received his Ph.B. (1906) and A.M. (1912) degrees. He did graduate work at the Johns Hopkins University, including a summer with a Hopkins group in Jamaica, B. W. I., and at Columbia and Yale Universities, this latter during a part of his service as First Lieutenant in the United States Army Sanitary Corps during World War I. Before military service interrupted work on his Ph.D., he taught biology at Southwestern College, Winfield, Kansas, at Haverford College, at the College of the City of New York, and at the University of Tennessee. He also taught during three summer sessions at the Johns Hopkins University.

After his release from military service in 1920, Mr. Givler joined the faculty of the Woman's College (then the North Carolina College for Women), at Greensboro, as Professor and Head of the Biology Department. He held this position for 29 years until his retirement in 1949.

Besides his classroom teaching and his work on numerous important faculty committees, Professor Givler found time for devoted work with church groups in the Greensboro community. He taught the Men's Bible Class at the Presbyterian Church of the Covenant for a dozen years. An accomplished musician from the time of his school days, he played cello with the Greensboro Symphony Orchestra. He was a Fellow in the AAAS, and a member of the honorary scientific Society of Sigma Xi. For many years he was a faithful and active member of the North Carolina Academy of Science. Besides work on various committees of the Academy, Professor Givler served as vice-president in 1924, and as president in 1925.

Professor Givler was the author of a *Textbook of Biology*, and, with the collaboration of some of his department colleagues, he wrote a *Laboratory Guide for General Biology*, which was revised in numerous editions. To various journals he contributed numerous short articles, concerned for the most part with biology teaching methods and materials. Among others of his special interests were genetics, evolution, crustacean morphology, embryology of the horned toad, and the relation between art and morphology.

On his retirement, in 1949, Professor Givler

turned his woodworking hobby into a vocation for repairing fine musical instruments, and in the following years he enjoyed painstaking precision and accuracy—and even strategy—in hundreds of repair jobs of varying degrees of difficulty.

Professor Givler had many fine qualities as teacher and as administrator, and his colleagues and the many students whom he taught and advised have profited much from his enthusiasm and from his thorough biological training, as well as from the wide area of his general knowledge and interests, and from his precise scientific attitude. In Professor Givler's passing North Carolina has lost a splendid teacher and a fine Christian gentleman, whose influence on our young folks will extend through generations to come.

Surviving Professor Givler are his wife, the former Miss Mary Shepherd, who was a member of his graduating class at Hamline University; a daughter, Mrs. G. G. Hines; two grandchildren; two brothers, Robert Givler, of Cape Cod, Massachusetts, and Fred Givler, of Cleveland, Ohio; and a sister, Miss Mary Givler, of Cornwall, Pennsylvania.

ARCHIE D. SHAFTESBURY

LEON FRANKLIN WILLIAMS

Leon Franklin Williams was born at Merchant Mills, Gates County, North Carolina, August 27, 1881. He received his early education in the public and private schools in Gatesville. In 1897, young Williams entered Trinity College (North Carolina), now Duke University. There he obtained in 1901 the degree of Bachelor of Arts, and in 1902 the degree of Master of Arts. At Johns Hopkins University, in 1907, he was awarded the Doctorate of Philosophy in organic chemistry. Dr. Williams spent a summer at Columbia University in the early nineteen twenties.

Except for two years as a Laboratory Assistant at Trinity College, his professional career of forty years was devoted to teaching and research at the North Carolina Agricultural and Mechanical College, now the North Carolina State College of Agriculture and Engineering.

From Instructor in Chemistry in 1907, he rose to the rank of Professor of Organic Chemistry, and in 1924–25 he served as Chairman of the Department of Chemistry. Thereafter, he continued to serve as Professor of Organic Chemistry until his partial retirement in 1947. In 1950, Dr. Williams became Emeritus Professor of Chemistry. During the summers from 1913 through 1919, Dr. Williams served as Chemist in the North Carolina Agricultural Experiment Station.

Although teaching was his first love, Dr. Williams was active in professional societies. In 1911 he was Vice President of the North Carolina Section of the American Chemical Society, and in 1912 he became President; he was Chairman for North Carolina of the American Chemical Society Essay Contests for High Schools from 1925 to 1933; he served on the Editorial Board of the *Journal of Chemical Education*; he was a member of the Committee for Standardization of Pronunciation of Organic Chemical Terms; he was a member of the Graduate Council, North Carolina State College, from 1924 to 1930; and he was a contributor to the *Handbook of Chemistry and Physics*.

In addition to membership in the American Chemical Society, he was a Fellow of the American Association for the Advancement of Science, Fellow of the American Institute of Chemists, member of the North Carolina Academy of Science, of the Honor Society of Phi Kappa Phi, and of Gamma Sigma Epsilon, Chemical Fraternity.

Research undertaken by Dr. Williams included studies of—acyl derivatives of ortho- and para-amino phenols; primary, secondary, and tertiary amine derivatives of camphoroxalic acid; gossypol in cottonseed hulls; effect of various amounts of copper and manganese upon tobacco; and copper in foods.

By nature Leon Williams was gentle and retiring. He was dedicated in fulfilling the duties of his profession, loyal to friends, and devoted as husband and father. He sustained crushing personal sorrow with exemplary courage.

His death occurred on April 4, 1957. His fellow-workers and other friends pay tribute to Leon Franklin Williams with affection and respect. A grateful college will cherish his memory.

G. HOWARD SATTERFIELD

JOHN OLIVER HALVERSON

Dr. Halverson died December 8, 1957, in Tuscon, Arizona, where he had made his home since retirement from North Carolina State College in 1946. He was born in Hanska, Minnesota, January 17, 1880. He received his B.A. degree in 1906 and his M.S. degree in 1907 from the University of Minnesota. He received an M.A. degree from the University of Missouri in 1913

and then studied a year at Yale. In 1916, he received the Ph.D. degree from Jefferson Medical College.

He spent 1908 as Assistant Chemist in charge of dairy investigations at the University of Missouri. From 1909 to 1912, he was deputy commissioner and chemist for dairy, food and drug inspection in the state of Missouri. In 1917, he moved to Ohio State University where he served as an associate in nutrition with the Ohio Agricultural Experiment Station.

Dr. Halverson was head of nutrition investigations in the Department of Animal Industry at North Carolina State College from 1920 to 1942, and was a Research Associate Professor until his retirement in 1946. He did extensive research in the field of nutrition and biochemistry. These investigations included studies of calcium in blood, calcium metabolism in cattle and swine, the soft pork problem, the utilization of cottonseed meal in animal diets, and methods for estimating gossypol in cottonseed products.

Dr. Halverson was a member of the North Carolina Academy of Science from 1920 until his retirement in 1946 and served as vice president for the year 1925–26. Dr. Halverson was a member of the American Chemical Society, The Society of the Sigma Xi, and a member of the Animal Nutrition Research Council.

The North Carolina Academy has lost a staunch supporter and those of us who knew him have lost a loyal friend.

F. H. SMITH

JAMES W. MOFFITT

James W. Moffitt was born in Tennessee in 1898 and died in High Point, N. C., July 10, 1956. After graduating from East Tennessee State Teacher's College he took a Master's Degree in history at Duke University in 1931. This was followed by many years of teaching history and government in several colleges. Then followed a period of seven years, 1937–1944, when he was Secretary of the Oklahoma Historical Society. In 1947 he won a Ph.D. in history at the University of Oklahoma. This was followed again by several years of teaching of history. While at Furman University he was elected a faculty member of Blue Key, national honorary scholastic and leadership fraternity in 1950.

In the evening of his academic career he came to High Point College as a teacher of history and education; during these years he became much interested in psychology. It was through this last interest that he became a member of the North Carolina Academy of Science.

Dr. Moffitt's interest in his students, and his unfailingly polite conduct when dealing with his colleagues, won him a host of friends who mourn his loss. He was in the best sense of the words a Christian gentleman.

VELMA DARE MATTHEWS

Velma Dare Matthews was born in Burlington, North Carolina, on August 3, 1904, the daughter of the late J. Marvin and Cora Moore Matthews. She grew up in High Point where she finished high school in 1921.

In 1925 she graduated with the B.A. degree from the North Carolina College for Women in Greensboro and the following September entered the University of North Carolina for graduate study in the Department of Botany. Here she was awarded the Master's degree in 1927 and the Ph.D. in 1930 working under the guidance of the late W. C. Coker.

For the year 1930–31 Dr. Matthews was Professor of Biology in the Agricultural and Mechanical College at Monticello, Arkansas, a position which she gave up during the illness and death of her mother. She served as Research Assistant and Librarian in the Department of Botany at Chapel Hill during the years 1931–1934. Much of this time was spent in helping prepare the illustrations and manuscript of *Trees of the Southeastern States* for publication. In 1934, she was appointed associate professor of biology at Coker College, Hartsville, South Carolina and the next year became Professor and Head of the Department, a position which she filled with distinction until her death.

Dr. Matthew's career shows a wide variety of talents and accomplishments. Her doctor's dissertation on the genus *Pythium* was published in book form by the University of North Carolina Press and was the first complete treatment of this genus in America. In addition she published several outstanding papers on fungi, the most notable of which was that describing the genus *Blastocladiella*, now becoming famous as an object for metabolic studies. In addition she contributed numerous papers to horticultural literature. Her published works showed exceptional brilliance in observation and interpretation.

At Coker College, she assumed responsibility for beautifying the campus and she was tireless

in working to improve the physical appearance of the town of Hartsville. Her part in bringing the William Chambers Coker Science Building into being was a notable achievement. This building, largely planned and carefully supervised in every detail by Dr. Matthews, is a worthy monument to her energy and drive. She was an inspiring and patient teacher.

During the recent years of ill health and suffering her courage was an inspiration to all. She maintained her interest in life and concern for others until the very day she lost consciousness. She died in Duke Hospital on January 7, 1958. By her untimely death, we have lost one of our distinguished and loyal members and the South, one of its most valued teachers.

EZDA DEVINEY, Coker College
JOHN N. COUCH

REPORT OF THE NOMINATING COMMITTEE

The committee, consisting of Reinard Harkema, D. B. Anderson and J. W. Lasley submitted the following nominations:

President: Gerald R. MacCarthy, University of North Carolina

Vice-President: L. A. Whitford, N. C State College

Secretary-Treasurer: John A. Yarbrough, Meredith College (for a term of three years)

Member of Executive Committee: Paul J. Kramer, Duke University

Member of Research Grants Committee: C. E. Jenner, University of North Carolina

The above nominees were unanimously elected by the Academy. This concluded the business and the meeting was adjourned.

Approximately 125 members of the Academy, guests and friends enjoyed the Annual Dinner of the Academy which was served in the Union Ball Room of Duke University at 6:30 p.m. Vice-President Victor A. Greulach presided over the banquet and a brief session which followed. Dr. Walter M. Nielsen of the Physics Department of Duke University presented greetings from the host school. The 1957 Potcat Award, presented annually by Phipps & Baird, Inc., Richmond, Virginia, was formally presented by President Berry to Dr. Knut Schmidt-Nielsen of Duke University for a paper given in the Biochemistry Section in 1957. The title of the paper was "Extrarenal secretion in birds." For the second year the John Bewley Derieux Memorial Award was given to a paper chosen as the best presented in the Collegiate Academy session. This presentation was made to Richard C. Stone of Duke University for a paper titled "The toxicity of some basic proteins tested in mice."

Dr. Thomas J. Turner of Wake Forest College was chosen as spokesman for the Physics Section of the Academy to present five teachers of high school physics who were particularly honored this year by that Section. Each had previously received notice of his selection as an outstanding teacher of high school physics, each had been named as an honorary Academy member for 1958, and each was presented to the banquet audience as an honored guest. The group included Frank N. Harton, Central High School, Charlotte; R. C. Hatley, Albemarle High School, Albemarle; J. Stanley Johnson, Greensboro High School, Greensboro; Clarence Shipton, Curry High School, Greensboro; and Daniel E. Todd, New Hanover High School, Wilmington.

Following the banquet the members and friends adjourned to the Chemistry Auditorium where President Berry presented an interesting Presidential Address on "The Triassic of North Carolina." Vice-President Greulach presented Dr. Berry and presided over the session. Following the lecture all members and guests were entertained at a delightful social hour in the Lounge of the Flowers Building, courtesy of Duke University.

The following officers were elected for the respective sections:

Biochemistry and Physiology: Chairman, Claude L. Yarbro; Secretary, Dr. Maude F. Williams

Botany: Chairman, Terry W. Johnson; Secretary, William J. Koch

Geology: Chairman, J. L. Stuckey; Secretary, Duncan Heron

Mathematics: Chairman, Alfred Brauer; Secretary, Ralph B. Johnson

Physics: Chairman, Raymond L. Murray; Secretary, R. M. Helms

Zoology: Chairman, Tom Daggy; Secretary, Charles M. Allen

The following constitute the personnel of the standing committees:

Executive: Gerald R. MacCarthy, L. A. Whitford, John A. Yarbrough, Maurice Whittinghill, Ben H. Hill and Paul J. Kramer

Research Grants: H. J. Oosting, T. H. Eaton, Ernest Ball and C. E. Jenner

At this writing Dr. MacCarthy, President of the Academy, has not appointed the persons for

the remaining committees. These will be named early in the autumn of 1958.

The following papers were presented during the meetings at Duke University. Those marked with an x are abstracted in these proceedings:

GENERAL SESSION

The IGY. Dr. J. W. Joyce, Head, Office for IGY, National Science Foundation

World warning network and the IGY. Dr. Roger C. Moore, Head, IGY World Warning Agency, National Bureau of Standards

Geomagnetism as related to IGY. Dr. J. H. Nelson, Chief, Geomagnetism Branch, Coast and Geodetic Survey

COLLEGIATE ACADEMY

Analysis of Wilson County ponds with reference to fish growth. W. B. Edwards, Jr., Atlantic Christian College

Factors influencing high school pupil's interest in science. Carolyn Hutchins, Appalachian State Teacher's College

The suitability of Wilson County pond water for the irrigation of tobacco. Jerome H. Rhodes, Atlantic Christian College

Effect of gibberellic acid on growth of orchids. William B. Fisher, Jr., Duke University

A study of sex ratio in swine. A. C. Hinton, Jr., East Carolina College

The toxicity of some basic proteins tested in mice. Richard C. Stone, Duke University

An analytic extrapolation of the tie lines on a triangular phase diagram. James M. Peterson, Wake Forest College

BIOCHEMISTRY AND PHYSIOLOGY SECTION

x *Effects of direct infusion of gaseous CO_2 in the dog*. John Salzano and F. G. Hall, Duke University

x *Toxicity of high oxygen pressures*. K. E. Penrod, Duke University

x *A method for observing valve action in the excised beef heart*. Wayland E. Hull and Eugene C. Crawford, Jr., Duke University.

x In vivo *observations of pulmonary arteries during and following embolization with minute autogenous clots*. William H. Knisely and John M. Clontz, Duke University

x *Hageman factor activation*. Charles L. Johnston, Jr., and John H. Ferguson, U.N.C.

x *The effects of rare earths upon rat liver lipids*. Bradford Miller, Carl E. Anderson, Claude L. Yarbro and Granvil C. Kyker, U.N.C. and Medical Division, Oak Ridge Institute of Nuclear Studies

x *A comparative study of the viscosity of nuclear gels from vertebrate tissues*. Virginia L. Seery, Duke University

x *The active site of xanthine oxidase*. Irvin Fridovich, Duke University

x *Equilibration studies on the urine of two patients with dental pulp stones*. Claude L. Yarbro, U.N.C.

BOTANY SECTION

x *The vegetational history of maritime Canada*. Dan Livingstone and Bertha Livingstone, Duke University

Ecological classification of flowers by pollination processes in nature. A. L. Pickens, Charlotte, N. C.

x *A report on the vascular flora of Rowan County, N. C.* James H. Horton, University of North Carolina

Variation in the Houstonia purpurea *group*. Edward E. Terrell, Guilford College

Flavonoid distribution in flowers of some woody plants. J. R. Troyer, N. C. State College

x *The effect of visible and ultraviolet light on oxidation of lipids in chloroplasts*. Anne Harmon, Duke University

Promotion of cell division in bean stems by gibberellin. John G. Haesloop and Victor A. Greulach, University of North Carolina

Studies on some sex-linked loci in Neurospora crassa. H. Branch Howe, Jr., Wake Forest College

x *Possible mechanisms of resistance in solanaceous plants to* Pseudomonas solanacearum. E. C. Maine and Arthur Kelman, N. C. State College

x *Lyophilization of Actinoplanaceae*. Charles E. Miller, University of North Carolina

x *Factors influencing sporangial production in* Phytophthora parasitica *var.* nicotianae. G. V. Gooding and G. B. Lucas, N. C. State College

Distribution of fungi in the Neuse and Newport estuaries. T. W. Johnson, Jr. and Harvey S. Gold, Duke University

A study of some algal enigmas. L. A. Whitford, N. C. State College

Uni-algal cultures for research and teaching. Elton C. Cocke, Wake Forest College

GEOLOGY SECTION

x *Wall structure of the Foraminiferal family, Endothyridae.* Joseph St. Jean, U.N.C.

A study of the geomorphic nature of the hillslopes of the Piedmont. Oscar Bradley Eckhoff, U.N.C.

x *North Carolina earthquakes: 1957.* G. R. MacCarthy and Evelyn Z. Sinha (Speaker), U.N.C.

x *An unusual depletion of artesian aquifer at Benson, North Carolina.* Harry LeGrand, Private Consultant

The recent Wilmington "Tremors". G. R. MacCarthy, U.N.C.

New geologic map of North Carolina. J. L. Stuckey, State Geologist

HIGH SCHOOL TEACHING SECTION

The Science Fair program in North Carolina. H. D. Crockford, U.N.C., State Director of Science Fairs

A trip to the National Science Fair. Robert Lancaster, Myers Park High School, Charlotte

(Student papers by four high school seniors placing high in the Fourth North Carolina State Science Talent Search)

Building a spectroscope. Alton Tripp, Jr., Needham Broughton High School, Raleigh

Moonwatch (satellite tracking). Russell Philbrick, Cary High School, Cary

Effects of temperature and stirring on crystallization of sugar solution. Susan Beatty, Needham Broughton High School, Raleigh

Development of a standard method of growing water-soluble inorganic crystals. William S. Hurt, Needham Broughton High School, Raleigh

T-V science experiments. Mrs. S. E. Denton, Woman's College, U.N.C.

MATHEMATICS SECTION

Procedures for tying property lines to circular curves. T. F. Hickerson, U.N.C.

x *Variable matrix substitution in algebraic cryptography.* Jack Levine, N. C. State College

x *The superior student program at State College.* L. S. Winton, N. C. State College

x *Some problems concerning residue class rings.* Drury W. Wall, U.N.C.

A second report on a mathematical postage stamp collection. Ralph B. Johnson, Catawba College

x *Proposal of a new system of structure.* Jehu D. Paulson, N. C. State College

x *Some statistical applications of Mellin transforms.* William Tunstall Wells, N. C. State College

x *On bases of sets of integers.* Hans Rohrbach, University of Mainz, Germany (Visiting Professor, U.N.C.)

The construction of ovals of Cassini. Alfred Brauer, U.N.C.

x *On foci of a conic.* J. W. Lasley, Jr., U.N.C.

PHYSICS SECTION

Millimeter-wave, molecular beam spectrometer for high temperature. Monroe Cowan, Allen Garrison, and Walter Gordy, Duke University

The Duke Van der Graaff program (invited paper). Henry Newson, Duke University

Nuclear reactors at North Carolina State College (invited paper). Raymond L. Murray, N. C. State College

x *Control rod analysis by three-group method.* George Forrest Hampton and Raymond L. Murray, N. C. State College

Experiment in intermetallic diffusion. Joel Snow, U.N.C. (sponsored by Lawrence Slifkin)

Some experiments on crystals of AgCl. John Harden, Jr., U.N.C. (sponsored by Lawrence Slifkin)

x *Atomic movements measured by an-elastic methods.* Thomas J. Turner, Wake Forest College

ZOOLOGY SECTION

An analysis of the population dynamics of the meadow mouse in Michigan. Frank B. Golley, U.N.C.

x *Resistance of sweet corn varieties to insects.* Charles H. Brett, N. C. State College

x *Hierarchial position and learning ability in the South African clawed frog,* Xenopus laevis *Daudin.* Robert Haubrich, East Carolina College

x *Check list of insects of the Great Smoky Mountains National Park.* Karl D. Snyder, Montreat College

x *Mitotic activity in remaining kidney of white mice after unilateral nephrectomy.* Charles E. McCreight, Bowman Gray School of Medicine of Wake Forest College

x *A new strigeid trematode from the pancreatic*

duct of the raccoon. Reinard Harkema and Grover C. Miller, N. C. State College

x *History of the tail bud and related structures in the terrapin and man.* W. C. George, U.N.C. Medical School

x *Speculations on the biology of a fossil midge.* D. A. Livingstone, Duke University

Distribution pattern in the mud snail, Nassarius obsoletus *of Sapelo Island, Georgia, as social behaviour.* Charles E. Jenner, U.N.C.

x *Some fishes found in tributaries of the French Broad River near Mars Hill, N. C.* L. M. Outten, Mars Hill College

x *An immunochemical comparison of two stages in frog development.* Mary Lee Barber, Duke University (introduced by E. C. Horn)

x *Histochemical changes in the regenerating intestine of the adult common newt.* W. Keith O'Steen, Duke University (introduced by E. C. Horn)

x *Induced recombination in relation to spontaneous crossing-over.* Maurice Whittinghill, U.N.C.

Anaerobic glycolysis in normal and atypical pigment cells of fish. D. G. Humm and Jane H. Humm, U.N.C.

The Effects of Venous Infusion of Gaseous Carbon Dioxide into Dogs. JOHN SALZANO AND F. G. HALL. It is possible to infuse relatively large quantities of gaseous carbon dioxide into the femoral veins of dogs at fairly rapid rates (100 ml STPD per minute) for several hours without fatal results and apparently without adversely affecting complete recovery. During a control period, period of infusion, and subsequent recovery period, blood pressure, carbon dioxide in expired air, tidal air and breathing rate, and blood gas content were measured. It was shown that carbon dioxide diffuses rapidly from blood to alveoli and that carbon dioxide can quickly be recovered in the expired air. As much as 19 liters (STPD) has been infused at a rate of 100 ml per minute with complete recovery.

Toxicity of High Oxygen Pressures. KENNETH E. PENROD. It has been known for a long time that high pressures of oxygen are toxic if breathed for a very long time by animals. But the mechanism of this toxic action remains obscure.

The toxicity appears to take two separate forms in laboratory animals: a central nervous system effect precipitating violent convulsions and ultimate death; and a severe hepatization of the pulmonary tissue resulting in severe damage to the exchange area of the lungs such that the animal ultimately dies from lack of oxygen. It has been the latter manifestation of oxygen toxicity that has been principally investigated here.

On the basis of a great many observations, it appears that oxygen under high pressure in some way causes an increase in the mucoid secretion of the pulmonary tissue which results in peripheral plugging of the distal airways resulting in a blockade of that portion of the lung beyond the plug. As a consequence of the blockade this portion of the lung collapses and in this way the lung tissue is rendered nonfunctional.

Substances that prevent pulmonary edema such as 20 per cent ethyl alcohol and commercial preparations designed to reduce surface tension offer significant protection but do not completely alleviate the situation. (This work was supported by a grant from the Office of Naval Research to Duke University.)

A Method for Observing Valve Action in the Excised Beef Heart. WAYLAND E. HULL AND EUGENE C. CRAWFORD. Direct observation of the structure and action of heart valves in a fresh preparation is of considerable value in teaching cardiovascular function. Recent advances in heart surgery, particularly for relief of valvular defects, has made necessary more precise understanding of the spatial and functional relationships of valves and their attachments. However, interest in visualization of internal structures of the heart is by no means recent. In 1886 Gad (Arch. f. Anat. u. Physiol.: 380) described his method for demonstrating the valves in the beef heart, combining in a certain degree the older methods which stem from as early as 1671. Tigerstedt, in 1913 (Tigerstedt's Handbuch der physiologishen Methodik. Leipzig: S. Hirzel, 1913, bd. 2, p. 188) included an article by Otto Frank, describing in detail the arrangement used to that time, and illustrated a method upon which our improved technique is based. The method described here draws attention to an improved sealing device to penetrate the ventricular cavity so that pulsatile pressures applied to the fluid contents of the heart simulate the effect of contraction of the ventricular wall. An electric light within the ventricle permits clear view of the mitral and aortic valves as fluid is circulated through the left side of the heart in quite a real-

istic manner. The use of this demonstration as a dynamic teaching model is described.

In Vivo *Observations of Pulmonary Arteries During and Following Embolization With Minute Autogenous Clots.* WILLIAM H. KNISELY AND JOHN M. CLONTZ. Clot emboli are frequently found in small pulmonary arteries in man at autopsy and it has been suggested that their organization leads to pulmonary hypertension and the clinical entity, "Chronic Cor Pulmonale" (Castleman and Bland, '46; Duguid, '49). These experiments were carried out to follow any visible *in vivo* changes, and to relate any changes found to histologic data.

Fine graphite was mixed with 10–30 drops of blood to more easily identify emboli. The clot which formed was passed through a sieve with 124 micron openings. The lungs of 28 rabbits were observed at magnifications from 25 to 900×, from a few minutes to 9 days after embolization.

Clots usually lodged near a bifurcation and sometimes blocked flow immediately. Collateral flow sometimes appeared beyond emboli but usually stopped in 1–2 hours. A pale precipitate formed around clot emboli. Clots became less distinct in a few hours. At 8–9 hours small particles were seen within capillaries over adjacent alveoli; other particles appeared to be within the vessel wall. Flow was usually restored within 18 hours and many particles then appeared to surround the vessel like a "cuff". In later observations the clot became less distinct until only a few discrete particles were seen in the vessel wall. Kodachrome photomicrographs were made and sections were made from lung, liver, spleen, adrenals, and striated muscle. Sections from lungs after acute injections contained many vessels plugged with emboli; inflammation and congestion were seen in a few hours; later, carbon particles were in capillaries and alveolar walls. Recannalized vessels were found at about the same time intervals as seen *in vivo*. Changes seen in vessel walls at later times agree with those reported by other investigators; namely, intimal hypertrophy and proliferation, recannalization of thrombi, and eccentric plaque formation.

Hageman Factor Activation. CHARLES L. JOHNSTON JR. AND JOHN H. FERGUSON. In blood clotting, the activation of plasma on contact with a foreign, "wettable" surface has been known for many years. Many hypotheses have been advanced to explain this phenomenon, but none seem completely satisfactory. It will be shown that Hageman factor, one of the more recently recognized clotting factors possessing thromboplastic activity, is activated on surface contact. This finding may reconcile many of the divergent views previously held.

Plasma which has been in contact with powdered asbestos shows a shorter clotting-time than untreated plasma, as measured in the Quick one-stage, standard and modified proconvertin, and partial thromboplastin time assays. When asbestos treatment was applied to a panel of normal and clotting-factor deficient plasmas, all the samples tested, except those in which the Hageman factor was lacking, showed shortened clotting-times.

It was further shown that Hageman factor, purified from normal serum and added to either normal or clotting-factor deficient plasmas, shortened all the clotting times below control values. An attempt was made to recover purified Hageman factor from the serum of a Hageman deficient individual. The resultant product was inactive and failed to accelerate the clotting-time of any plasma to which it was added.

The similarity between asbestos-activated plasma and a purified Hageman factor preparation, coupled with the failure to show equivalent activity in Hageman deficient plasma, demonstrates the primary role of the Hageman factor in surface activation of plasma.

The Effect of Rare Earths upon Rat Liver Lipids. BRADFORD MILLER, CARL E. ANDERSON, CLAUDE L. YARBRO, AND GRANVIL C. KYKER. Liver lipids from rats were analyzed after intravenous injections of 3.5 mgm. per kgm. of body weight of lanthanum, cerium, praseodymium, or neodymium. Rats injected with saline served as controls. The animals were sacrificed at 1 and 4 hours, 1, 2, 4, 6, 10, 14, and 21 days after injection, and the lipids were extracted by homogenizing the liver with alcohol-petroleum (1:3) ether. After separating and evaporating the petroleum ether the lipids were taken up in fresh petroleum ether for analysis. Total lipids were determined gravimetrically, total cholesterol by the Liberman-Buchard reaction stabilized with p-toluenesulfonic acid, total phosphatides by the Fiske-Subbarow procedure and acetal phosphatides by the Feulgen-Andresen-Boguth method

as modified by Yarbro. Total lipids and total cholesterol showed marked elevations at 2–4 days returning to normal by the 6th day. Total phosphatides showed no acute changes. Acetal phosphatides, on the other hand, showed an elevation at 2–4 days paralleling the levels of total lipids and total cholesterol. This would suggest that acetal phosphatides are possibly closely related to changes in the cholesterol and neutral fat fractions.

A Comparative Study of the Viscosity of Nuclear Gels from Vertebrate Tissues. VIRGINIA L. SEERY. Tissue and species specificity of deoxyribonucleoprotein was investigated by measuring the viscosity of 1 M NaCl extracts of rat, turtle, and bluefish tissues. A logarithmic relationship was found between deoxyribonucleic acid (DNA) content and maximum apparent relative viscosity of the extracts. The relationship between apparent relative viscosity and DNA content of the same tissue of different individuals was fairly constant. Rat thymus extracts were found to have an average slope of 1.27 ± 0.21; liver extracts, a slope of 2.85 ± 0.91; and spleen extracts, a slope of 2.99 ± 0.72. When comparisons were made at the same DNA concentration, rat liver and spleen extracts were found to be approximately 2.3 times as viscous as rat thymus; turtle liver extracts were 2.5–3.3 times as viscous as turtle kidney or spleen. Species specificity of viscosity-DNA relationships was suggested by comparisons between rat and turtle tissues. Rat spleen extracts in media buffered at pH 6.7 were approximately 2 times as viscous as turtle spleen of the same DNA content; rat liver was 0.7 times as viscous as turtle liver. The viscosity behavior of bluefish tissues was found to be strikingly different from rat and turtle tissues; at high DNA concentrations, fish liver and spleen extracts had a low viscosity. It was suggested that differences in DNA and in the binding of DNA with protein may function in imparting specificity at the tissue and species level.

The Active Site of Xanthine Oxidase. IRWIN FRIDOVICH AND PHILIP HANDLER. Studies of the interactions of milk xanthine oxidase with purines and with inhibitors have led to a postulated structure of the active site of this enzyme which appears to be consistent with its known properties (Fridovich and Handler, J. Biol. Chem., in press).

'Substrates' bind onto and transfer electrons directly to one molecule of FAD. The electrons then pass to each of a pair of ferric mercaptides which are reoxidized by passing the electrons to a second molecule of FAD which is then able to reduce oxygen or methylene blue. The second FAD, like the first, has an affinity for substrate and its combination with substrate prevents it from interacting with oxygen or dyes, thus giving rise to the phenomenon of excess substrate inhibition.

Additional support for this concept has been sought by experimental tests of predictions of the behavior of the enzyme under various circumstances derived from the suggested nature of the active site. To date, all observations have been in accord with the proposed structure.

Equilibration Studies on the Urine of Two Patients with Dental Pulp Stones.[1] CLAUDE L. YARBRO. The mechanism of formation of abnormal calcifications in the pulp of human teeth is unknown although hyperparathyroidism, avitaminosis A, and hypervitaminosis D have been suggested as factors involved in pulp stone formation. Currently, investigations of the problem of urinary calculus formation is being investigated in this laboratory, by following the patterns of changes in calcium, magnesium, phosphate, oxalate and citrate in the urines of normal and renal calculus subjects following equilibration of the urines with solid phase tricalcium phosphate, secondary calcium phosphate and calcium oxalate. The question arose concerning the possibility that similar equilibrations of the urine of dental pulp stone patients might show a pattern similar to that of renal calculus subjects. Accordingly the urines of two subjects with dental pulp stones, as established by X-ray diagnosis, were studied by the method mentioned above. Comparison of the results with those obtained on normal and renal calculus subjects revealed similarities in the nature of the changes in calcium and phosphate content of the urine of pulp stone patients with those of renal calculus subjects where tricalcium phosphate was used as the solid phase for the equilibrations.

The Vegetational History of Maritime Canada. DAN LIVINGSTONE AND BERTHA LIVINGSTONE. Cordilleran species of plants occur as eastern disjuncts in the region around the Gulf of St.

[1] Supported by a research grant (PHS A-248) from the National Institute of Arthritis and Metabolic Diseases of the National Institutes of Health, Public Health Service.

Lawrence. As the species are predominantly ones of open vegetation, the disjunct populations have been interpreted as relicts from a time when open vegetation prevailed from the Atlantic Ocean to the Cordillera, permitting transcontinental continuity of range. Pollen analysis of lake sediments in eastern Canada has been used to demonstrate the existence of a broad band of tundra or park tundra around the margin of the last continental glacier from the time of deglaciation, about 13,000 years ago, until about 10,000 years ago. Presumably the disjunct species had a much wider range during that time, probably from the Gulf of St. Lawrence to the Rockies.

A Report on the Vascular Flora of Rowan County, North Carolina. JAMES H. HORTON. Rowan County, bordered by Davie, Davidson, Stanly, Cabarrus, and Iredell Counties, is near the center of the Piedmont Plateau. Many botanists, including A. A. Heller and J. K. Small, have collected in the county, but none have attempted a complete vascular flora of the county. This paper grew out of such an attempt.

Ten of the more interesting plants collected are cited below. With the exception of the first, the genera are listed alphabetically. The collection number is given. Specimens are deposited in the herbarium of the University of North Carolina.

Dentaria multifida Muhl. Alluvial woods, south bank of the Yadkin River, w. of NC 49 bridge. 1039, 1470.

This species is not cited for North Carolina by Montgomery in his 1955 paper, "Preliminary studies in the genus *Dentaria* in eastern North America" (Rhodora **57:** 165), and is, therefore, assumed to be new for the state.

Anemone caroliniana Walt. On granite, Dunns Mtn., 4 mi. s.e. of Salisbury. 791.

Bromus tectorum L. Railroad yard, Salisbury Railroad Depot. 1224.

Centaurea maculosa Lam. Roadside, 2.8 mi. w. of Landis, 1.1 mi. n. of Enochville. 1387.

Cirsium carolinianum (Walt.) Fern. & Schub. Roadside, 3.6 mi. w. of Craven, 5.8 mi. n. of Rockwell. 1272.

Convolvulus spithamaeus L. Railroad embankment, 1.2 mi. s.e. of Gold Hill on US 52. 1056.

Gillenia trifoliata (L.) Moench. Foot of a Kalmia bluff, and oak woods, South Yadkin River, just downstream from the mouth of North Second Creek. 955, 962.

Lychnis coronaria (L.) Desr. Fallow field, 5.4 mi. w.n.w. of Enochville. 1389.

Phragmites communis Trin. Between highway and railroad embankment, south bank of the Yadkin River, e. of US 29 bridge. 494.

Tragopogon major Jacq. Roadside, US 601 bridge across the South Yadkin River. 1235.

These and other interesting finds indicate that the Piedmont Plateau is worthy of further floristic study.

The Effect of Visible and Ultraviolet Light on Oxidation of Lipids in Chloroplasts.[2] ANNE HARMON. Pure unsaturated fatty acids are subject to autoxidation, yielding conjugated hydroperoxides. The reaction is catalyzed by ultraviolet light, and by visible light in the presence of chlorophyll. Several studies have demonstrated that aerobic incubation of animal tissues results in the formation of products of fatty acid oxidation, probably including hydroperoxides. In view of these findings, the effect of visible light and ultraviolet light on lipid peroxide formation in chloroplasts from spinach, turnip, and tobacco leaves was investigated.

Incubation of chloroplasts in visible light resulted in an increase in lipid peroxide formation. Incubation in ultraviolet and visible light produced more peroxides than incubation in visible light alone. In the absence of light little peroxide was formed. The reaction was catalyzed somewhat in the dark by the addition of iron. The addition of EDTA or boiling the chloroplast preparation resulted in a decrease in peroxide formation due to light. Preliminary experiments indicated that lipid peroxides were not formed in whole leaves exposed to light, probably because of an antioxidant. An antioxidant which prevented lipid peroxide formation was found in the supernatant of homogenates of turnip leaves.

Possible Mechanisms of Resistance in Solanaceous Plants to Pseudomonas Solanacearum. E. C. MAINE AND ARTHUR KELMAN. Growth of *Pseudomonas solanacearum*, causal agent of bacterial wilt in solanaceous plants, was inhibited in all parts of inoculated resistant tobacco plants. The synthesis of inhibitory components was apparently a light-dependent process occurring in the leaves. Presence of compounds in resistant plants toxic to the wilt bacterium could not be demonstrated by agar diffusion techniques. Sterilization of sap from resistant solanaceous plants

[2] Supported by a grant from the Atomic Energy Commission.

apparently removed or inactivated inhibitory components. However, a component of unsterilized juice from resistant tobacco plants was inhibitory to the pathogen. Concentrations of scopoletin and an unidentified phenolic compound increased in tobacco plants following infection, with greatest increase occurring in susceptible plants. Of the tobacco varieties tested, resistant plants contained more chlorogenic acid than susceptible ones. Unlike reduced chlorogenic acid, which was only bacteriostatic, oxidized chlorogenic acid was bacteriocidal to the wilt bacterium *in vitro*. Results indicate that chlorogenic acid may be involved in the mechanism of inhibition of *P. solanacearum* in resistant plants.

Lyophilization of Actinoplanaceae. CHARLES E. MILLER. The lyophile apparatus and preparation techniques devised for freeze-drying the Actinoplanaceae were described and illustrated. A relatively simple method requiring the minimum of special preparation and equipment was found to work satisfactorily. A ten inch length of pyrex glass tubing, 9 mm o.d. and 7 mm. i.d., is heated in the middle, the two portions drawn apart and sealed. The open end is fire-polished. 0.2 cc of suspending solution, double strength Difco dehydrated skim milk, is pipetted into these lyophile tubes. The tubes are autoclaved for 15 minutes at 15 pounds pressure. A 1.5 inch piece of chromel wire is fashioned to a spatulate shape and attached to a loop holder. Three week-old, regular stock cultures of Actinoplanaceae growing on peptone Czapek agar (peptone Czapek agar causes the mycelium of most of the Actinoplanaceae to "heap up" thus making it easy to avoid transfer of much agar) are used as inocula. The inoculum is inserted all the way down the narrow lyophile tube into the suspending solution, and while located thus, the end of the transferring tool is rotated back and forth rapidly. The spatulate-shaped end acts as a beater, dispersing the inoculum in the suspending solution.

Tubes prepared as above are snap-frozen in dry ice and solvent at minus 60°C for 10–15 minutes. After a vacuum of 100 μ or less is achieved in the freeze-dryer, the tubes with the frozen suspending solution and dispersed inocula are inserted in the ports of the freeze-dryer. The contents of the tubes are vacuum dried for 1.5–2.0 hours. They are then sealed off under vacuum.

160 isolates were tested after 3–4 months; all were found viable. Growth occurred from vast numbers of pieces of mycelium, both microscopic and macroscopic in size. The vitality of the isolates was not apparently impaired.

Factors Affecting Sporangical Production in Phytophthora Parasitica *Var.* Nicotianae. G. V. GOODING AND G. B. LUCAS. Sporangia of *Phytophthora parasitica* var. *nicotianae* are produced in abundance if aerial mycelium of 14 day old cultures is stripped from oatmeal agar plates, wetted and incubated for 6 or more days at 24°C, providing an isolate is used that carries the potential for abundant sporulation. Air appears necessary for sporangial production, and light does not. Of seven solutions tested, maximum sporulation occurred in 1/100 M KNO_3 solution and minimum in double distilled water. The cardinal temperatures for motility and germination of zoospores were 8, 20 and 32°C. Zoospores remained motile longer and more germinated in 1% dextrose solution than in distilled water, tap water or complete nutrient solution. At a concentration of 1,000,000 spores per ml. distilled water, more than 50% of the spores were motile after 4 hours. When this was diluted 1000 times, no zoospores were motile after 5 minutes.

Wall Structure of the Foraminiferal Family Endothyridae. J. ST. JEAN, JR. Wall structure is considered to be the most fundamental character in all modern Foraminiferal classifications. Two different concepts have influenced our thinking on the wall structure in the family Endothyridae. First, that all arenaceous or agglutinated tests are primitive, and that calcareous tests were derived by an evolutionary reduction in the amount of foreign material and corresponding increase in calcareous cement. Therefore, the members of an early family, such as the Endothyridae, which range from the Devonian to the Permian, should have agglutinated tests. The granular appearance of the surface of the test, the distinct finely granular wall structure as seen in most thin sections, and a small amount of insoluble residue associated with dissolved tests tend to suggest an agglutinated test for the Endothyridae. The second concept is that arenaceous tests are evolved polyphyletically, and that most Foraminifera with arenaceous tests are terminal members along several evolutionary lines rather than primitive. According to the latter school, the Endothyridae have a calcareous "fibrous" test. Therefore, the lack of an agglutinated test does not conflict with the primitive nature of the Endothyridae. The latter concept is based on the wall

structure seen in thin sections of well-preserved members of the family Endothyridae, and from one or two of the larger genera of the family which have abnormally thick "fibrous" tests.

Thin sections were made of six of the twelve genera of the Endothyridae. The granular structure seen in most thin sections of endothyroid tests was found to be a recrystallization phenomenon, not the result of the cementation of foreign mineral matter with excessive amounts of calcareous cement. It is possible, in selected examples of both large and small members of the Endothyridae, to demonstrate a gradation within the same specimen from the typical "fibrous" structure to the recrystallized finely granular structure. In well-preserved tests, there is no difficulty in recognizing the minute details of the endothyroid test wall, which has structures comparable to the diaphanotheca wall structure of the primitive genera of the family Fusulinidae. The work partly corroborates the recent work by Robert H. Cummings (1956, Micropaleontology, vol. 2, p. 201–242, pl. 1) on the wall structure of the Paleozoic family Paleotextulariidae.

North Carolina Earthquakes: 1957. GERALD R. MACCARTHY AND EVELYN Z. SINHA. During 1957 there were at least three small earthquakes in western North Carolina, none of which caused any real damage, but which were strong enough to be recorded on seismographs at Chapel Hill, N. C. and at Columbia, S. C. These shocks form part of an apparent sequence which started with the September 28, 1955 shock on the North Carolina-Virginia border. The epicenters of these earthquakes lie along a slightly curved line which more or less parallels the Blue Ridge Front, and which may be associated with the Blue Ridge Fault which has been postulated by William A White and others.

A Freakish Depletion of an Artesian Aquifer at Benson, North Carolina. HARRY E. LEGRAND. A very permeable sand and gravel bed, 20 to 40 feet thick, overlies slaty bedrock at a depth of about 200 feet in Benson. Prior to the first town well in 1917, the water table in the surface sand, the water level of the sand and gravel bed, and the water level represented by the fractured bedrock were all about 15 feet below the land surface.

No wells have drawn water directly from the sand and gravel; the five productive town wells, ranging in yield from about 25 to 200 gallons a minute, have drawn water directly from fractured bedrock deeper than 200 feet. Pumping of the bedrock wells has resulted in drainage of water from the sand and gravel into the underlying rock fractures. The drainage exceeds the rate of recharge. Thus, the sand and gravel bed, whose artesian water level was originally more than 125 feet above its top, is almost completely unsaturated; its water level is only a foot or two above its base and above bedrock. Since the sand and gravel bed is not known to crop out, recharge of water to it and then to the underlying bedrock fractures is limited by the low vertical permeability of the overlying clays.

The situation is unique in that a permeable artesian bed has been locally depleted without water having been drawn directly from it. It is also unusual because air is trapped in an artesian system. The inability of the air to escape retards recharge as downward leakage from the overlying saturated clays.

Wells serving three purposes could greatly increase the town's water supply. These include:

1. Wells to expel the entrapped air.
2. Recharge wells transmitting water from the surface to the sand and gravel.
3. Production wells.

Variable Matrix Substitution in Algebraic Cryptography. JACK LEVINE. The matrix congruence $C \equiv AP$, where A is an n by n matrix with fixed elements a_{ij} and P and C are one-column matrices, has been used to form an enciphering system converting a plain-text sequence $p_1p_2 \cdots p_n$ to a cipher-text sequence $c_1c_2 \cdots c_n$. This present paper gives some methods for using a matrix A with variable elements to accomplish this type of encipherment. Variable element matrices are obtained whose elements are linear in a parameter, the matrices satisfying the condition $A \equiv A^{-1}$.

The Superior Student Program at N. C. State College. L. S. WINTON. This paper is concerned with the present and projected status of the Superior Student Program at North Carolina State College. The intent of the program to provide a more certain and sound education for these students and to guide them towards future graduate work is stated explicitly.

The portion of this program devoted to mathematics is detailed. The sequence, followed by a ten week review of enriched Algebra and analytic Trigonometry, is as follows. A Calculus and Analytic Geometry pattern is followed for the first year. The second year includes Vector methods applied to Solid Analytic Geometry

and to Partial Differentiation, other more usual topics, and ends with Differential Equations. Certain difficulties in the administration of the program and the selection of "Superior Students" closes the discussion.

Some Problems Concerning Residue Class Rings. DRURY W. WALL. Several problems will be stated here and partial answers given concerning residue class rings. Let A and B denote rings, X and Y denote classes of rings, Z, Z', etc., denote two-sided ideals, and Q, Q', etc., denote types of two-sided ideals. If A is a ring and Z is a two-sided ideal of A then A/Z will denote the residue class ring of A with respect to Z. For a ring A and a type Q, define $Q(A) = \{Z \mid Z \text{ is an ideal of } A \text{ and } Z \text{ is type } Q\}$. For a class of rings X and a type Q, define $[X, Q] = \{A \mid Z \in Q(A) \rightarrow A/Z \in X\}$.

The first problem is: *For which choices of X, Y and Q is it true that: $X = [Y, Q]$?* A theorem of this type gives a characterization of a ring in a class in terms of conditions upon its residue class rings. It is known that such theorems hold if Q is all two-sided ideals, X is the class of uniserial algebras, and Y is any of the following classes of algebras: uniserial, weakly symmetric, Frobenius or quasi-Frobenius. A similar sequence of theorems can be proved in which Q is the class of all two-sided ideals, X is the class of generalized uniserial algebras and Y is any of the subclasses of the UMFR algebras (algebras with unique minimal faithful representations) which contain the generalized uniserial algebras as a subclass.

The second problem is: *For which choices of X, Y and Q is it true that: If $A \in X$ then $\exists B \in Y$ and $\exists Z \in Q(B)$ such that $A \cong B/Z$?* A theorem of this type states that any ring in a class X can be represented as a residue class ring of some ring in the class Y. In the case that $Y \subset X$, the problem is stated: What classes of rings X can be represented as residue class rings of a proper subclass? For example, although it is known that not all residue class algebras of a Frobenius algebra need be Frobenius, the properties of such residue class algebras are not yet fully known.

Proposal of a New System of Structure. JEHU D. PAULSON. Proposal is made of a new system of structure more effectively employing the tensile strength of metal by means of equilateral triangular framework and panels.

Some Statistical Applications of Mellin Transforms. WILLIAM T. WELLS. In statistical work it is often very difficult to obtain the distribution of the product of two random variables, say x and y, which have distribution functions $f(x)$ and $f(y)$ respectively. One of the best methods of attack seems to be the operational method of the Mellin transform. The use of Mellin transforms in obtaining the distribution of products has been treated before by Epstein [*Annals of Mathematical Statistics*, **19** (1948) 370–379]. The advantage of the Mellin transform comes from the fact that the Mellin transform of the distribution of a product of independent random variables is the product of the Mellin transforms of the individual distributions. A simple example of finding the distribution of the product of two random variables with rectangular distributions is solved in the usual manner and with Mellin transforms to illustrate the procedure.

The use of Mellin transforms can be extended to the problem of finding moments of distributions. From the Mellin transform of the distribution function the value of any moment about the mean can be found by merely substituting the correct numerical value of s (the transform variable) into the transform. This method is simpler than other methods when the Mellin transform is easy to obtain. Therefore, in these cases it is easy to study the moments of the distribution of products without finding the actual distribution.

On Bases of Sets of Integers. HANS ROHRBACH. Given two sets A, B of nonnegative integers, $0 \in A \cap B$, then the set $A + B = \{a + b, a \in A, b \in B\}$ is called the *sum* of A and B. This addition of sets is commutative and associative. Therefore the sum of a finite number h of sets is uniquely determined. In case all sets of this sum are equal to, say, A the sum is denoted by hA. Let N be the set of all nonnegative integers. Then a subset A of N is called a *basis of order h* if $hA = N$, i.e. if every n of N is representable as a sum of at most h elements of A. If, in addition, some n are not representable by less than h elements, A is called a *basis of exact order h*. For instance, if $A = \{1^2, 2^2, 3^2, \cdots, n^2, \cdots\}$ then $h = 4$, and 4 is the exact order. A corresponding definition applies to the case where a subset M of N instead of N is con-

sidered. Then A is called a *basis of order h for M* if $hA \geqq M$.

The author gives a short report on the work done by him and some of his fellow research workers, especially Alfred Stöhr (Free University of Berlin) and Erich Härtter (University of Mainz), on the following problems: (i) The existence of a basis of order h. To prove this a very simple method of constructing a basis is given. (ii) The average order for the number of its elements. For every basis of order h this is equal to $O(\sqrt[h]{n})$. (iii) Investigations on minimal bases. The best one of the nine existing different definitions of a minimal basis in the opinion of the author is: B is called a *minimal basis of order h* if no proper subset of B still is a basis of order h. In every basis of order h there is a subset which is a minimal basis of this order. The set of all minimum bases of order h (even of exact order h) has the power of the continuum. Both theorems remain valid if the concepts are extended to k-bases of order h, that is to bases of order h by which every positive integer can be represented in at least k different ways.

On the Foci of a Conic. J. W. LASLEY, JR. An expository paper comparing different methods of approach to the problem of foci of a conic, their existence, their determination. Comments upon the wealth of theorems, due to Steiner, Desargues, Pascal, Brianchon, Von Staudt used in solving the problem.

Control Rod Analysis by Three-Group Method. GEORGE F. HAMPTON AND RAYMOND L. MURRAY. A method of estimating control rod reactivity by three-group neutron diffusion theory is analyzed for a bare, cylindrical, homogeneous reactor with a centrally located control rod.

From the three-group diffusion equations representing neutron behavior in a critical reactor, the buckling equation is derived and the nature of the roots is analyzed. The coupling coefficients and the critical condition are derived for two cases: (a) when the three buckling roots are real, and (b) when one root is real while the other two are complex conjugates. The boundary conditions involved in the derivation of the critical determinant are the values of the extrapolation distance at the boundary of the control rod for each neutron group and the extrapolation of flux to zero at the extrapolated boundary of the reactor.

By a simplifying analysis of the critical determinant, a method is obtained for estimation of control rod reactivity from materials constants for the critical reactor with no control rod. Sample calculations of control reactivity indicate that epithermal neutron absorption in the control rod can contribute significantly to the reactivity of the rod.

The epithermal absorption effect and the simplification of the critical determinant, by means of which the three-group calculations for simple geometries are not unreasonably difficult with the aid of a desk calculator, make the three-group method practical for control rod analysis in survey-type problems.

Atomic Movements Measured by An-elastic Methods.[3] THOMAS J. TURNER. The capacity of a vibrating solid to convert its mechanical energy of oscillation into heat, even when so well isolated that energy losses to its surroundings are negligible, is called internal friction. The most common manifestation of internal friction is the damping, or loss of vibration amplitude of a freely vibrating body. Studies of this type are now widely used to investigate internal structure and atomic movements in solids.

Three types of equipment were described which have been constructed at Wake Forest College to measure internal friction over a large range of frequencies. To measure relaxation times and hence rates of atomic movement of the order of one second a torsion pendulum was described. An-elastic after-effect measurements were described which enable one to determine relaxation times of the order of 1000 seconds. These techniques have been described by Wert (1957. Acta Met. **5:** 41).

Relaxation time determinations of the order of one ten thousandth of a second were described. The specimen, a rod one-quarter inch in diameter, is clamped at its center and vibrates in its fundamental made as a result of an eddy current drive. One end of the specimen forms a capacitor in an F.M. detection system. This apparatus was patterned after that developed by D. O. Thompson (Rev. Sci. Insts. to be published).

These studies are being made in an effort to understand the mechanism of stress induced atomic motion in alloys.

[3] Supported in part by a Frederick Gardner Cottrell Grant from the Research Corporation.

Resistance of Sweet Corn Varieties to Insects. CHARLES H. BRETT. Thirty commercial varieties of sweet corn were tested during 1957. Damage by the corn earworm was measured in terms of percentage of ears infested and degree of damage per ear. Infestation ranged from 34% to 88% between the varieties. This did not correlate with egg deposition or length of the husk beyond the ear tip. Apparently many factors are involved in resistance and these may differ for each variety. It was also found that Japanese beetles attacked the silks of some varieties to a greater extent than others. This damage affected pollination. Three species of sap beetles (Nitidulidae) were present. Their damage to kernels ranged from slight to heavy among the sweet corn varieties. Some varieties were completely destroyed by the fall armyworm, others produced some edible ears. It has generally been impractical to attempt to grow sweet corn during late summer and fall because of fall armyworm damage.

Hierarchical Position and Learning Ability in the South African Clawed Frog Xenopus laevis *Daudin.* ROBERT HAUBRICH. Frogs were placed in a "T" maze one at a time with water as the goal at the end of one of the arms and dry cloth at the other. Each animal was run ten trials daily for 30 consecutive days and was kept isolated. Events in the maze were recorded as pauses, time taken to complete the run, turns and errors. Definite learning curves were obtained in all cases for each series of daily trials, but no indication of learning was noted when daily trials were compared for the 30 days. When placed in pairs or groups these animals established a type of hierarchy based upon relative number of nips given and received. Animals showing a moderate amount of aggression, i.e. in the middle of the hierarchy, made the fewest errors, turns and took the least time to complete the trials, yet paused in the maze more often. Animals nipping the least made the most errors, turns and took the most time for the runs.

1957 check list of insects of the Great Smoky Mountains National Park. KARL D. SNYDER. This is a check-list of over 2600 species of insects collected within or immediately surrounding the Great Smoky Mountains National Park. About half of the insects are represented by determined specimens in the Park collection. Other sources of information are Brimley's "Insects of North Carolina" and letters and reprints on file in the office of the Park Naturalist. It is hoped that this list will help to stimulate research within the Park in the form of summer field courses. The Park is well equipped to serve small groups of students from local colleges and universities. Both the colleges and the Park would benefit from such research.

Mitotic Activity in Remaining Kidney of White Mice after Unilateral Nephrectomy. CHARLES E. MCCREIGHT. Mitotic figures are infrequent in the epithelia of the normal kidney. The enlargement of the remaining kidney after unilateral nephrectomy in the rat has been shown to involve increased mitotic activity in cells of tubules of all types, which is well under way after three days (Sulkin, 1949). In the present study young adult white mice, male and female, have been used in determination of the amount of increase of mitosis under these conditions. Colchicine was employed as an enzyme poison to halt mitosis beyond the metaphase and to allow accumulation of mitotic figures for an interval of time.

In one group of animals the right kidneys were removed by dorsal incision, and after 72 hours each animal received an intraperitoneal injection of 0.5 c.c. 1:10,000 colchicine:saline solution. Eight hours later the mice were sacrificed by perfusion with formalin-gum arabic-saline solution via the right ventricle of the heart. Control animals were unoperated, but received similar colchicine treatment and perfusion. Remaining kidneys of nephrectomized animals and both kidneys of control animals were embedded in paraffin, sectioned at 10 microns, and stained with the Feulgen nuclear stain and fast green.

Observations and counts of cells of the proximal tubules of kidneys of each category were made. Percentages of cells in mitosis were calculated in order to compare the mitotic activity in the proximal tubules of enlarging kidneys with that of normal kidneys.

A New Strigeid Trematode from the Pancreatic Duct of the Raccoon. REINARD HARKEMA AND GROVER C. MILLER. Examination of a raccoon on December 15, 1957, revealed the presence of eighty-six specimens of a trematode in the pancreatic duct. These worms had caused marked hypertrophy of the pancreatic duct and consequent swelling of the pancreas. The specimen proved to be a strigeid, but is sufficiently different from any known form to constitute a new genus. This trematode is characterized by the presence of a very large, elongated holdfast organ contained within an elongated pouch of the ventral

body wall. In this respect it is similar to the genus *Duboisiella*, but differs from it in the structure of the holdfast, which is not lobed; testes side by side; the absence of an ejaculatory pouch; and the presence of pseudo-suckers. It also shows similarity to *Pharyngostomum* and *Pharyngostomoides* in the arrangement of the testes. However, the distinctive holdfast and ventral pouch separate it from these genera.

The History of the Tail Bud and Related Structures in Reptiles and Man. W. C. GEORGE. Following the formation of the primitive streak in the embryo of the terrapin, there grows forward from the primitive knot a head process between the ectoderm and endoderm. This has a broad lumen and the opening into it is the blastopore. The floor of this lumen disintegrates bringing the blastopore into communication with the potential gut cavity, thus forming the neurenteric canal. After the tail fold has formed and given rise to the hind gut the primitive streak with its neurenteric canal becomes the tail bud. As the tail bud grows caudally feeding out mesoderm, neural tube, and notochord, it carries a continuation of the hind gut with it. This is the tail gut or post anal gut.

Examination of a series of human embryos reveals a similar sequence of events in human development.

Normally, in both reptile and human, after the typical number of somites has been formed, proliferation in the tail bud subsides, the notochord and neural tube terminate in the connective tissue derived from its remnants, the tail gut disappears, and the neurenteric canal will have closed, usually earlier.

Exceptionally, in man, tumors, cysts, fistulae occur that can be interpreted as being derived from persisting structures that normally disappear or from continued proliferation and chaotic differentiation of mesenchyme of the tail bud.

Speculations on the Biology of a Fossil Midge. D. A. LIVINGSTONE. The genus *Dryadotanytarsus* is known only as a fossil larva from lake deposits. Its distribution is bipolar and its known stratigraphic range spans the last 13,000 years. The mandibles are toothless and the labium rolled around the hypopharynx, but the food on which this remarkable feeding apparatus was used is completely unknown. One possible explanation for the very spotty distribution of *Dryadotanytarsus* through space and time is that it is restricted to lakes which have a meagre fauna, either because of their youth, or because of their rigorous environment. If this explanation is correct, then the midge may live today in some of the farm ponds of North Carolina.

Some Fishes Found in Tributaries of the French Broad River near Mars Hill, N. C. L. M. OUTTEN. From September, 1949, to April, 1958, one hundred collections of fishes were made in twenty-six tributaries of the French Broad River near Mars Hill, Madison County, North Carolina. The twenty-nine species found, with the number of collections in which each was observed in parentheses, are as follows: *Notropis galacturus* (72), *Campostoma a. anomalum* (70), *Notropis rubricroceus* (58), *Hypentelium nigricans* (57), *Rhinichthys atratulus obtusus* (53), *Hybopsis micropogon* (47), *Notropis leuciodus* (44), *Hybopsis a. amblops* (41), *Notropis coccogenis* (40), *Etheostoma flabellare* (31), *Notropis spilopterus* (30), *N. spectrunculus* (25), *Etheostoma swannanoa* (19), *Micropterus d. dolomieui* (7), *Ambloplites rupestris* (6), *Moxostoma duquesnei* (4), *Rhinichthys cataractae* (4), *Catostomus c. commersoni* (3), *Cottus bairdi* subsp. (3), *Hybopsis* sp. (3), *Micropterus salmoides* (2), *Notropis ariommus telescopus* (2), *Carassius auratus* (1), *Lepomis macrochirus* (1), *Moxostoma erythrurum* (1), *Notropis rubellus* (1), *Percina evides* (1), *Phenacobius uranops* (1), and *Salmo gairdneri* (1). These observations were associated largely with a study of the life histories of *Notropis coccogenis, galacturus*, and *rubricroceus* conducted under the guidance of Dr. Edward C. Raney of Cornell University.

An Immunochemical Comparison of Two Stages in Frog Development.[4] MARY LEE BARBER. Chemical and physical characterization of antigenic mixtures found in the supernatant fraction of homogenates of mature ovarian oocytes and hatched larvae of *R. pipiens* (Shumway stage 19–20) was attempted by treating the supernatant with fractionation agents among which the most productive were 1) ammonium sulfate, 2) trichloroacetic acid, 3) fat solvents, and 4) 76°C. and 100°C. The effectiveness of the treatments was determined by the presence or absence of antigens as represented by lines with the Ouchterlony agar diffusion technique employing rabbit antisera prepared against the whole supernatant preparations. The wells in the plates were

[4] This work was supported in part by research grants RG3555 and CY3252 from the National Institutes of Health, Public Health Service.

arranged in such a manner that serologically related and non-related antigens could be distinguished readily by the continuity or overlap of their resulting lines in the plates. Seven antigens were demonstrated in the mature oocyte and six in the hatched larvae. The results of the fractionation procedures as tested serologically strongly suggested the presence of lipid or carbohydrate conjugated groups. Each antigen of either developmental stage was related in some manner to at least one antigen of the other developmental stage as shown by continuities in the agar plates. Several more complex serological relationships were demonstrated when more than one line from one developmental stage fused with but a single line of the other stage. An hypothesis was constructed to explain 1) this latter complexity of continuity, 2) the differences in the number of lines present in heterologous reactions when compared with the homologous reactions, and 3) the difference in effectiveness of the fractionation treatments on the related antigens from the two stages. For any set of antigens, for example those of the mature oocyte, a molecular complication leading to demonstrable chemical differences may arise during embryonic development, allowing at the same time retention of identical antigenic sites. The serological cross-reactivity accompanied by chemical differences between the antigens of the two developmental stages may be explained on this basis.

The Histology of the Regenerating Intestine of the Adult Common Newt. W. KEITH O'STEEN. A series of experiments were undertaken to determine the regenerative capacity of the intestine of the adult common newt, *Diemyctylus* (*Triturus*) *viridescens*. The operation consisted of a single transection of the intestine approximately equidistant between the pylorus and the rectum. Groups of animals were killed at regular intervals after the operation to determine the chronological sequence of histological changes.

After the operation the sections of intestine were replaced in the coelom in no definite order.

During the first ten post-operative days adhesion of intestinal sections to one another occurred. Two cut surfaces adhered in some cases, while in others the cut surface of one section adhered to the lateral surface of the other section of the intestine. The early blastema which formed at the cut surfaces was composed of mesenchymatous cells, leucocytes, and collagenous fibers. In 86 per cent of the animals tissues other than the intestine adhered to the blastema. These tissues adhered in the following sequence of descending frequency: liver (69%), fat body (66%), ovary (31%), parietal peritoneum (26%), testis (20%), lung (9%), urinary bladder (6%), and oviduct (6%).

The most striking early histological change occurred in the submucosa. It became edematous and distended by the engorgement of lymph spaces and blood vessels. This distention continued to spread from 5 to 10 mm anteriorly and posteriorly from the transection.

Between the tenth and the twentieth post-operative day histological changes were observed both in the intestine and in the adhering tissues. The serosal cells changed from their normal spindle-like shape into large spherical cells containing a globular nucleus. These cells frequently had cytoplasmic extensions and were amoeboid in appearance. The cells of the smooth muscle layers appeared to separate from one another and to transform into cells with atypical nuclei. These cells were observed passing into the blastema. No change other than that mentioned above was observed in the submucosa. Some mucosal cells, arising from extensions of mucosa which at this time were pushing through the substance of the blastema from each section of the intestine, passed into the blastema and contributed to its formation. The mucosal extensions of the anterior end of the intestine contacted the extensions from the posterior end during the fourth post-operative week, completing the restoration of the lumen. After this time food was observed passing through this newly formed area. The other tissues which were adhering to this area also contributed cells to the blastema. Cortical and medullary cells of the liver were observed passing into the blastema. Follicle cells of the ovary and interstitial cells of the testis morphologically dedifferentiated and moved into the blastema. In a similar manner the striated musculature of the body wall dedifferentiated and appeared to contribute to this mass of mesenchymatous cells.

Intestinal tissues regenerated from the blastema in the following chronological sequence: mucosa, serosa, submucosa, and muscularis. The muscularis reformed by an alignment of the mesenchymatous cells of the blastema in a position adjacent to the intact muscularis of both ends of the intestine.

The blastemal mass gradually decreased as the

new tissues regenerated. By the late stages of regeneration (50–80 days) all tissues other than the intestine separated from the blastema, and it was impossible to distinguish grossly the former area of transection.

Induced Recombination in Relation to Spontaneous Crossing Over. MAURICE WHITTINGHILL. An environmental effect upon the chromosomes was demonstrated in 1917 by Plough, who showed that temperature extremes greatly increased the frequency of recovered crossover phenotypes from *Drosophila* females. The time delay in increase indicated that crossing over of linked genes did not take place in the second maturation division but earlier. Other agents—X-rays, gamma rays, and nitrogen mustard—also increase values of recovered crossovers after several days; and the increases are similar in pattern, being greatest in the spindle attachment region and progressively less distally. The simplest inference from the above is that the increases are directly related to increased crossing over at meiosis.

Yet when the same agents—heat, X-rays, gamma rays, and also formaldehyde—are applied to *Drosophila* males, a different picture emerges for that sex. Each of the four agents has produced clusters of similar crossover sperm, such as would require supplementary hypotheses if all crossing over were restricted to meiosis. Furthermore, it has been shown that crossing over is both initiated and completed in a four strand stage in a spermatogonial cell of an X-rayed male heterozygous for one or more recessive lethals. Because both sexes are alike in the regional pattern of induction or increase, one may reopen the question of whether the classic increases described as early meiotic in females may not be, in part or wholly, premeiotic.

The above reasoning may extend from treated specimens to controls, in that excessive variability of recombination percentage characterizes (1) induced crossovers among males, (2) increases of crossovers among treated females and even, (3) as shown by Gowen in 1919, among control females. A unified explanation of the above three observations may be based upon the strong somatic pairing found in *Drosophila* and other Diptera. In the wasp *Habrobracon* no increases and no exceptional variability like (2) and (3) were found in recent experiments using X-rayed females. Two alternative simple conclusions are possible: either that meiosis in *Habrobracon* is not susceptible to increases in crossing over under the action of X-rays while meiosis in *Drosophila* is; or that in neither is meiosis affected, but that a low level of gonial crossing over in *Drosophila* females gives erratic spontaneous recombination percentages and that the action of inducing agents is upon such gonial cells of either sex resulting in even greater variability from family to family.

PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY
1957–1958

538TH MEETING, OCTOBER 8, 1957

R. E. GLOVER (Physics): *Outlines of the Theory of Superconductivity.* Recent experiments in the long wave infrared and millimeter microwave wavelength regions have given a clearer picture of the superconducting state. They indicate the presence of a "gap" in the energy level density distribution of a superconducting metal. Theories have recently been advanced to explain the presence of this gap.

G. K. SUMMER (Pediatrics): *Protein Fractionation in Health and Disease.* Protein fractionation by zone electrophoresis and the adaptation of this procedure for evaluation of changes in plasma protein components has been the subject of intensive investigation for a number of years. This paper presents studies on plasma protein fractions from birth to adulthood and in disease states with emphasis on the variables affecting the accuracy and reproducibility of the paper electrophoretic method—paper structure, moisture content, temperature, current, and liquid flow. With these conditions controlled, paper electrophoresis can be used for two dimensional separation of amino acids, turnover of serum proteins, localization of enzymes in biological mixtures, and identification of degradation products of proteins and peptides.

For clinical purposes paper electrophoresis offers a simple tool for analysis of complex mixtures, particularly simple and conjugate proteins that may change during pathologic processes. Although the method is potentially limited for diagnostic purposes, the results often give valuable ancillary data in many diseases and serve as a useful guide to the efficacy of therapy.

539TH MEETING, NOVEMBER 12, 1957

T. FUJII AND H. C. THOMAS (Chemistry): *Applications of a Method for the Measurement of Self-Diffusion in Wet Aggregates.* An account was given of a rather generally applicable method for the measurement of self-diffusion of ionic species possessing gamma-emitting isotopes. (The details are given in the Proceedings of the National Academy of Sciences, *42*, 909 December 1956.) The method has been applied to the measurement of the self-diffusion coefficients of sodium in agar gels. Mention was made of the possible physiological importance of such studies.

The method is also applicable, with more difficulty, to heterogeneous aggregates such as wet clays. The nature of several clay minerals was reviewed and it was shown how experiments now in progress should eventually shed light on the kinetics of ionic motion in these aggregates. Knowledge of this kind will be of importance in widely separated fields of study, such as the study of plant nutrition and the prediction of the long-time motion in the soil of the radioactive fission fragments.

540TH MEETING, DECEMBER 10, 1957

B. J. PETTIS (Mathematics): *Some Aspects of the Structure of Mathematics.*

J. CASSEL (Epidemiology): *Some Current Concepts of a Modern Epidemic—Coronary Heart Disease.* The hypothesis was advanced that the nature of the major health problems afflicting communities is closely associated with certain aspects of the way of life of those communities. This concept was briefly illustrated by reviewing some of the major health problems of the Western World in relation to changes in the way of life since the Industrial Revolution.

The evidence linking two aspects of the modern way of life, the diet and level of activity on the job, with the major health problem of contemporary society, coronary heart disease, was briefly presented.

541ST MEETING, JANUARY 14, 1958

C. E. JENNER (Zoology): *Social Behavior in Marine Mud Snails. A Summer's Research at the Marine Biological Laboratory, the Ideal University.*

W. A. WHITE (Geology): *The Origin of the Florida Lakes.* The larger lakes of Florida occur in a long, narrow, essentially straight zone which extends along the axis of the peninsula from Orange Lake at the north to Lake Okeechobee at the south. This zone is essentially co-extensive with the area where a blanket of sand rests on soluble limestone. Within it the lakes occur where surface drainage has been preserved, and where

the piezometric surface is higher than the surface of the ground.

It is suggested that the lakes result from solution on the upper surface of the limestone caused by water moving horizontally through the sand cover in places where the water table is high enough to remain within the sand. The high piezometric surface prevents any loss to deep circulation. This assures a voluminous horizontal discharge immediately below the water table and facilitates solution at the upper surface of the limestone.

This hypothesis is supported by the absence of lakes in the Everglades and the Chiefland Limestone Plain, two areas of exposed limestone where the piezometric surface is above the land surface, but there is no appreciable sand cover.

The large "disappearing" lakes of northern Florida seem to be relics of a former extension of the present zone of permanent lakes. They occur in places where the piezometric surface is now below the land surface but was formerly above it. All of them occur along the courses of former streams which have lost their water to subterranean drainageways.

542ND MEETING, FEBRUARY 11, 1958

H. ROHRBACH (Mathematics): *Some Applications of Mathematics to Cryptanalysis.*

J. F. DASHIELL (Psychology): *The Role of Vision in Animal Spatial Orientation.* The frequently stated theory that vision is essential in the organizing of a spatial world as a domain and not as specific distances and places was given experimental examination. White rats blind from birth (enucleation within 24 hours under hypothermia or supercooling) were introduced under hunger motivation to a multiple-pathway maze. It had been experimentally demonstrated previously that normal seeing rats could quickly establish their general orientation to the foodbox goal making it possible for them to pursue a wide variety of specific routes, many of them new, to this goal without error. And this after all possible intra- and extra-maze sensory cues had been eliminated. In the research here reported the animals with no visual experience of any sort, past or present, promptly demonstrated the same capacity to build up a spatial world of general character. Incidentally, many cases were observed in which the blind animals avoided new obstacles in their pathways—presumably by echolocation.

543RD MEETING, MARCH 11, 1958

J. STRALEY (Physics): *Some Observations on Scientific Training and Research in Italy.*

J. N. COUCH (Botany): *Taxonomic Criteria in Actinoplanaceae.* When the genus *Actinoplanes* was described, we had only a few collections, and the genus and species seemed relatively easy to characterize. As our collection has grown to more than 500 isolates, it has become increasingly difficult to settle on hard and fast generic and specific characters. This difficulty is in large part caused by the great variation of the Actinoplanaceae in artificial culture and by the fact that such variations may bring on the loss of some of the more important diagnostic characters.

With this new family one of our major problems has been to find out what characters are most reliable for taxonomic purposes. After considerable experimenting with natural and artificial culture media, it has been found that the structure and behavior of the sporangia and spores when the organisms are grown on *Liquidambar* pollen are of primary value in determining the generic and specific relations. Growth characters on artificial culture media, while not usually of basic value in determining relationships, are of secondary use taxonomically.

On the bases of sporangial and spore characters it is possible to recognize five very distinct groups in the family as follows: (1) *Actinoplanes* with spherical to very irregular sporangia and motile, subglobose spores; (2) a new group with more or less cylindrical sporangia and motile rod-shaped spores; (3) another group with exceedingly irregular sporangia and non-motile, short, rod-shaped spores; (4) one collection with spherical sporangia and weakly motile, bent rods or spiral spores; (5) *Streptosporangium*, with spherical sporangia and spherical to subspherical non-motile spores. Other morphological features such as the structure of the sporangial stalks are of considerable value. Further studies are needed before we can decide if all of these groups are of generic rank.

544TH MEETING, APRIL 8, 1958

H. H. STRUPP (Psychology and Psychiatry): *Psychotherapy and Scientific Observation.* Psychotherapy is a controlled interpersonal relationship integrated for the purpose of effecting favorable changes in the patient's living through the

systematic application of psychological techniques. Psychotherapy differs from other forms of psychological influence which have been practiced for many generations in its emphasis on the specification of conditions under which therapeutic results are achieved. The therapist, as a participant observer, creates a "laboratory" situation in which the patient's interpersonal processes are studied under controlled conditions. There is today a great body of clinical knowledge; however, future research must transform this knowledge into scientific principles of greater precision. As in other disciplines, the scientific method is used in psychotherapy to analyze complex phenomena to the end of making them amenable to human understanding and control.

J. ST. JEAN, JR. (Geology and Geography): *The Fossil Hydrozoan* Stromatoporella *Nicholson. Stromatoporella*, a Silurian to Devonian member of the order Stromatoporoidea, is characterized by a series of superposed laminar or concentric calcareous plates called laminae, 0.05 to 0.3 mm thick, separated by short vertical pillars 0.05 to 0.3 mm in diameter. The laminae are inflected upward in conical fashion forming hollow ring-pillars 0.2 to 0.4 mm in diameter. The laminar tissue is transversely fibrous or has many small anastomosing tubules.

Specimens of Middle Devonian *Stromatoporella* collected from southern Ontario, particularly at Thedford and Gorrie, are unusual in being adapted to a muddy rather than clear water reefal environment as most stromatoporoids. The laminar skeleton is abnormally thin, 0.5 to 10 mm thick, and has an unusually thick basal structure, the peritheca. Vertical and tangential thin sections of the peritheca were made for the first time, showing the initial skeletal structure to consist of calcareous material, not organized into laminae, pillars, or ring-pillars, but ramified by tubes 0.2 to 0.4 mm in diameter. The tubes seem to be related to astrorhizal canals, radial tubular structures found in the main part of the skeleton of most stromatoporoids.

545TH MEETING, MAY 13, 1958

The Coker Award for this year was presented to Stephen Duncan Heron, Jr. for a dissertation entitled: *The Stratigraphy of the Outcropping Basal Cretaceous Formations between the Neuse River, North Carolina, and Lynches River, South Carolina.* The outcropping basal Cretaceous beds between the Neuse River, North Carolina, and Lynches River, South Carolina, have been referred to the Tuscaloosa formation and to the "lower" part of the Black Creek formation, both of which were called Upper Cretaceous. This study has shown that these beds may be subdivided into three units: the Cape Fear formation, the Middendorf formation, and the Bladen member of the Black Creek formation.

The Cape Fear formation is exposed in outcrops along the Cape Fear River and its tributaries in Cumberland and Hoke Counties, North Carolina, and may be represented by beds poorly exposed along the Neuse River in Wayne County, North Carolina. The formation is characterized as alternate layers of compact quartz wackes and thin layers of mudstones without rapid lateral and vertical changes in lithology.

The Middendorf formation is exposed in much of the Sandhills of North and South Carolina. The formation is characterized as a mass of loose sand with associated mudstone layers and lenses. Rapid lateral and vertical changes in lithology are characteristic.

The Bladen member of the Black Creek formation is exposed along the major rivers in the Low Country of North and South Carolina. It is characterized as dark gray fissile, laminated shales in combination with large masses of loose sand. Rapid lateral and vertical changes in lithology are characteristic.

The stratigraphic relations among the three formations are not clear, but the available evidence indicates that the Middendorf formation is at least in part the landward facies of the Bladen member of the Black Creek formation. In the Fayetteville area of North Carolina, the Bladen-Middendorf overlies the Cape Fear. In the Peedee River area of South Carolina, the Cape Fear formation is absent. Here, the "lower" part of the Middendorf is a facies of the Bladen.

The Bladen-Middendorf is best developed south of the southeast plunging Cape Fear Arch. The Cape Fear formation occurs only on the northeast flank of the Arch.

The following business was also transacted:

538th meeting, October 8, 1957. Seventy-one

associate members were elected, and sixteen full members were nominated and elected.

539th meeting, November 12, 1957. Two associate members were elected and one full member, R. E. Glover (Physics).

542nd meeting, February 11, 1958. Four people were elected to full membership: Eugen Merzbacher, B. S. DeWitt, Cecile M. DeWitt (Physics), and James C. Wallace (Mathematics).

545th meeting, May 13, 1958. The Treasurer's report was read, and the Auditing Committee (J. L. Irvin and V. I. Mann) reported the books and accounts in order.

The Nominating Committee (W. L. Engels, W. A. Bowers, and V. A. Greulach) presented the following nominees for 1958–9:

President—Roy L. Ingram

Vice-president—Albert E. Radford

Secretary-Treasurer—Herman O. Thompson

Dr. Thompson will continue to serve for another year. The slate was unanimously elected.

HERMAN O. THOMPSON, *Sec.-Treas.*

THE ZOOLOGY LIBRARY OF THOMAS JEFFERSON

By Marion B. Savin and Harold J. Abrahams

Germantown, Philadelphia, Pennsylvania

Thomas Jefferson displayed a keener interest in and greater mastery of science than any other American President. Uncommon as are these attributes, it is even more rare for any one to win the distinction of playing a great role in helping to establish a new science, or of pioneering in another. Jefferson won both in the realm of animal studies. His paper:

> "A Memoir on the Discovery of certain Bones of a Quadruped of the Clawed Kind in the Western Parts of Virginia,"

read before the American Philosophical Society in 1797 was a great factor in the creation of the new science of paleontology. His work in assembling all available data on the Hessian fly, which was threatening to destroy our wheat and other grain crops, was done while he was chairman of an American Philosophical Society Committee, in 1792, (and Secretary of State of the United States). This was America's first organized effort in economic entomology, and shows Jefferson in his favorite activity of putting science to use for the benefit of mankind, for his deep concern was always with utility. His associations with the early work in paleontology and economic entomology are but two of the many evidences of his great interests in zoology. A few others are his successful efforts to disprove Buffon's claim that domesticated animals have degenerated in America, his continued interest in fossil bones, and his concern for animal health by vaccination. He even held views, though erroneous ones, on yellow fever and on animal nutrition.

Jefferson had already shown an interest in the fossil bones in his

> "Notes on the State of Virginia" (1782–1784).

The find of mammoth bones in Ohio and the Indian traditions that large creatures still existed to the north fascinated Jefferson and developed in him an interest in searching for bones of large quadrupeds. He underwrote the cost of such searches and made reports of them to the American Philosophical Society. His interest in fossil bones became so acute that in 1797 while journeying to Philadelphia for his inauguration as Vice-President of the United States he carried with him a large collection of newly discovered bones and a full set of notes on his studies of them. It must astonish us to picture this world-famous statesman arriving in the nation's temporary capitol accompanied by a bone collection which shared his interest with his duties of State. Within a few days he was to read the "Memoir" referred to above (to an audience which included the famous English chemist Joseph Priestley), and thus set free a force which had great effect in establishing the science of paleontology. In this paper he expressed the belief that if this animal, which he called the "Great-Claw" or "Megalonyx," (see item 39-i, below) once existed, "it is probable on this general view of the movements of nature, that he still exists." He was one of the first Americans to investigate fossil animal remains. This memoir on the first remains of the giant sloth found in North America appeared in 1799 and was the only scientific memoir ever published by him. Henry Fairfield Osborn has called him a pioneer American vertebrate paleontologist.

The early days of the year 1801 were fraught with great political tension. The House of Representatives was called upon to resolve the tie vote of the electors between Jefferson and Burr for the presidency. Jefferson, with monumental calm, remained at least outwardly unmoved. He placidly wrote scientific letters (to Dr. Caspar Wistar and others) on the subject of some bones of the Mammoth recently discovered in Ulster County, New York. Then a few weeks after his inauguration as President he wrote an expression of his hope that Americans would show an awareness of scientific advancement. Jefferson's membership in the American Philosophical Society enabled him to put science to use for the public welfare. His Committee of the Society, referred to above, collected materials

> "for forming the natural history of the Hessian fly and [for studying] the best means for its prevention or destruction."

Thus, he hoped he could get the members of the society to gather the latest information and plan an attack. Conferences were held but no committee report seems to have been made.

Jefferson was very active in planning and

drawing up instructions for the expedition of André Michaux to the Northwestern Territory in 1793. Michaux was to

> "take notice of the country .... its productions—animal, vegetable and mineral—so far as they may be .... useful or very curious.... Under the head of animal history, that of the mammoth is particularly recommended to your inquiries, as it is also to learn whether the Lama or Paca of Peru, is found in those parts of this continent, or how far north they come."[1]

Jefferson's controversy with the Comte de Buffon is interesting not only as one more evidence of his enthusiasm for zoology but also as a record of one of his investigations. Buffon had advanced his theory that in America domesticated animals, unlike those in Europe, degenerate in size, ascribing the decline to our colder and more moist climate. Jefferson, after much thought, reached the reverse conclusion. He held the view that Buffon lacked the necessary knowledge of our climate and geology to reach valid conclusions. From his own investigations and wide correspondence he gathered much material, which he arranged in the form of three tables, comparing weights of animals. His first table showed seven out of twenty-six of the animals common to both continents to be of equal size. His second table showed that one animal peculiar to America, the tapir, weighed more than the total of eighteen quadrupeds peculiar to Europe. In the third table he produced evidence from which it could be concluded that with equal care and food our domestic animals could reach equality with their European ancestors. Buffon's theory that the American Mastodon or "Mammoth" was the same as the African or Asiatic elephant annoyed Jefferson, who paid for and presented to Buffon specimens of bones and skin of a moose, horns of moose, caribou, elk, deer and American roebuck. The sections on animals in "Notes on the State of Virginia" and the extensive records he kept and many letters he wrote about horses, mules, steers, cows, sheep, goats, and hogs give further evidence of Jefferson's interest in animals.[2]

In addition to the prima facie evidence of Jefferson's interest in the study of animal life presented above there exists much additional evidence. Probably his most important scientific accomplishment was the part which he played in the Lewis and Clark Expedition. Having selected Captain Meriwether Lewis as its leader and confessing to himself that Lewis had all the necessary qualifications except a "complete" knowledge of the sciences, he sent a note to Dr. Benjamin Smith Barton on February 27, 1803, saying that Lewis would call upon Barton in Philadelphia in two or three weeks and requesting the doctor to give Lewis written and verbal instructions

> "in the lines of botany, zoology, or of Indian history, which you think most worthy of inquiry and observation."

He always regarded zoology as one of the most useful and practical of the sciences. When he planned to send his grandson Thomas Jefferson Randolph to Philadelphia to be educated, he made certain that natural history (at Peale's Museum) and anatomy at "The Medical School" would be included in his studies. Just before he died he showed his continuing respect for zoology by writing to Dr. John P. Emmett, Professor of Natural History at the University of Virginia (which Jefferson founded), about the various disciplines of Natural History and advising that the course for that year in Emmett's department should contain one dozen lectures in zoology.

Jefferson's interest in human and animal health kept him up-to-date with the latest developments in medicine. All of the members of his family were vaccinated against smallpox. He wrote Jenner on May 14, 1806:

> "Yours is the comfortable reflection that mankind can never forget that you have lived. Future nations will know by history only that the loathsome smallpox has existed and by you has been extirpated."

Concerning yellow fever he was confused. To Governor (later President) W. H. Harrison he expressed the belief that it was caused by excessive sunshine, but a few years later he wrote the Comte de Volney that he thought a chemical in the atmosphere was to blame. Interested in problems of balanced diet and nutrition, he was likewise limited by the current lack of knowledge on the subject. Yet he thought about

> "a moveable airy cow house to be set up in the middle of the field which is to be dunged, and soil our cattle in that through the sum-

[1] Lipscomb, Andrew J. (Editor-in-chief). 1903. "The Writings of Thomas Jefferson". Thomas Jefferson Memorial Association. XVII: 336–337. (Instructions to Andrew Michaux for Exploring the Western Boundary, Jan. 1793)

[2] Betts, Edwin Morris. 1953. "Thomas Jefferson's Farm Book". Princeton University Press. 87–147.

mer as well as winter, keeping them constantly up and well littered."

Thomas Jefferson's written statements on zoology give us additional insight into his great respect for the subject:

"Mathematics, Natural Philosophy, Natural History, Anatomy, Chemistry, Botany will become amusements for your hours of relaxation and auxiliaries to your principal studies. Precious and delightful ones they will be" (Letter from Jefferson to T. M. Randolph July 6, 1787)

"There are other branches of science however, worth the attention of every man: Astronomy, botany . . . . natural history, anatomy. Not indeed to be a proficient in them; but to possess their general principle and outlines, so as that we may be able to amuse and inform ourselves. . . . In Natural history we possess knowledge, but we want a great deal" (Letter from Jefferson to William Greene Munford, June 18, 1799)

"I will venture even to sketch the sciences which seem useful and practicable for us, as they occur to me while holding my pen. Botany, chemistry, zoology, anatomy . . . ." (Letter from Jefferson, to Joseph Priestley January 18, 1800.)

"Natural History . . . . is my passion . . . ." (Letter from Jefferson to Harry Innes, March 7, 1791.)

". . . . for a country gentleman I know of no source of amusement and health equal to botany and natural history . . . ." (Letter from Jefferson to T. M. Randolph, November 1808.)

Thomas Jefferson assembled at least three libraries. His first, known as the "1770" library was destroyed by fire. The second was purchased from him by the government of the United States in 1815 and became the nucleus of the Library of Congress. Of nearly eight thousand books in this collection there were about eight hundred on the sciences. Many of these he purchased while in Paris, devoting every free afternoon for a summer or two to visits to all the principal book stores

"turning over every book with my own hand and putting by everything . . . . rare and valuable in every science. . . . ." (Letter from Jefferson to Congressman Samuel H. Smith.)

A third library ("catalogue of Nathaniel Poor") was sold in 1829. The many zoology books in all three of these, especially the collection of 1815, which is the subject of this study, give additional and eloquent testimony of his love of the subject.[3] He used no bookplate, relying upon "printers signatures" for his initials. After a printer's "T signature" he would write the letter "J," or in front of an "I (for J) signature" he would write the letter "T," thus having a secret identification mark in each book. Only one of the zoology books in the 1815 collection (number 2, below) survived the fire of 1851 and other ravages.

(The spelling and punctuation of the quotations herein are Jefferson's own, no attempt at "modernization" having been made. The designations 4^{to}, 8^{vo} and 12^{mo} have the usual meanings "quarto," about eight by eleven inches, octavo, six by nine, and duodecimo four by seven, respectively. The books are predominately in English or French, with only seven in Latin and four in Italian.)

The "1815" library contained the following works on Zoology:

1. VALMONT DE BOMARE, JACQUES CHRISTOPHE. *Dictionnaire raisonné Universel d'Histoire Naturelle.* 9 volumes, 12^{mo}.

Jacques Christophe Valmont de Bonnare (1731–1807) was a French naturalist.

2. WINSLOW, JAKOB BENIGNUS - BRUHIER D'ABLAINCOURT, JEAN JACQUES.
The uncertainty of the Signs of Death, and the Danger of Precipitate Interments and Dissections, Demonstrated . . . . To the Whole is added, A curious and entertaining Account of the Funeral Solemnities of many Ancient and Modern Nations exhibiting Precautions they made use of to ascertain the Certainty of Death. London: 1746. 12^{mo}.

This is based on a French translation by Bruhier d'Ablaincourt, a French doctor (d. 1756), who was an early writer on the dangers of premature burial. Jefferson called him "a Physician of great eminence."

[3] Zoology was much in Jefferson's mind. To President Willard of Harvard, he wrote in 1789 ". . . . America's Natural History or Zoology [is] totally mistaken and misrepresented" and to W. G. Munford on June 18, 1799, ". . . What an immensity in every branch of science yet remains to be discovered. . . . In anatomy . . . much is still to be acquired. In Natural History we possess knowledge but we want a great deal. . . . "

The work was originally written in Latin (Paris, 1740) by Jakob Benignus Winslow (1669–1760), Danish anatomist of Paris, where he was Professor of Anatomy. He himself miraculously escaped premature burial.

The English translation is by an unknown person. This is the only remaining zoology book, of all those sold to the government by Jefferson, which escaped loss by fire or other kinds of destruction.

3. BRUCKNER, JOHN

A Philosophical Survey of the Animal Creation, an Essay. Wherein The General Devastation and Carnage that reign among the different Classes of Animals are considered in a new Point of View; and the vast Increase of Life and Enjoyment derived to the Whole from this Institution of Nature is clearly demonstrated. Translated from the French (By Thomas Cogan) .... London: 1768. 12^{mo}.

John Bruckner (1726–1804) was born in the Island of Cadsand and finally became pastor of a Walloon Congregation in Norwich. The work was also translated into German.

Thomas Cogan (1736–1818) was an English physician and philosopher.

4. BURKHARD, JOHANN GOTTLIEB.

Elementary or Fundamental Principles of the Philosophy of Natural History: leading to a better knowledge of the Creator and the Creatures, and especially of the destination and dignity of Man. Translated from the German by Charles Smith. New York: 1804. 12^{mo}.

Page 63 of this work bears a reference to C. W. Peale's Mammoth and a footnote by Smith:

> "Near the river Ohio, and some parts of North America, some prodigious bones and teeth have been discovered, which indicate an animal of incredible magnitude. It is known among naturalists by the denomination of the mammoth."

The book contains other references to America. Customs of Negroes, the savages of Canada, of Virginia, of Brazil and most of South America are discussed.

Johann Gottlieb Burkhard (1756–1800) was Minister of the German Lutheran Church in London.

5. SMITH, SAMUEL STANHOPE.

An Essay on the Causes of the Variety of Complexion and Figure in the Human Species. To which are added Strictures on Lord Kaims's Discourses, on the Original Diversity of Mankind. Philadelphia: 1787. 8^{vo}.

Samuel Stanhope Smith (1750–1819) was a Pennsylvanian and a Presbyterian minister. He was President of the College of New Jersey (later known as Princeton) and Professor of Moral Philosophy. This Essay was the annual oration (of 1787) of the American Philosophical Society, of which he was a member.

6. PLINIUS SECUNDUS, CAIUS.

C. Plinii Secvndi Historae Mvnci Libri XXXVII ... Frankfort, 1608. 8^{vo}.

Pliny the Elder (c.23–79) wrote works on numerous subjects, but only his "Natural History" is extant. This work of 37 books was presented to Titus in the year 77 A.D. It was enriched and revised from time to time until Pliny's death, which resulted from his efforts to observe the eruption of Vesuvius more closely and to aid the people who were in danger.

The work, encyclopedic in character, deals with the applications of science to human life—(geography, medicine, history of art, etc.)

This edition is by Jacques Dalechamp (1513–1588), French physician and botanist. It contains two critical essays on Pliny.

7. PLINIUS SECUNDUS, CAIUS.

Naturalis Historiae, cum commentariis & adnotationibus Hermolai Barbari, Pintiani, Rhenani, Gelenii, Dalechampii, Scaligeri, Salmasii, Is. Vossii, & Variorum. Leyden, Rotterdam, 1668, 1669. 8^{vo}.

Pliny's Natural History (see under 6 above), with commentaries by many other writers, whose names appear in the title.

8. PLINIUS SECUNDUS, CAIUS.

Historie Naturelle de Pline. Paris: 1771–82. 4^{to}. Twelve Volumes.

This is a French translation of Pliny's Natural History, with critical notes, and a comparison between science in ancient and in modern times. Latin and French texts are given on opposite pages, with notes below the text.

Jefferson tried to purchase "a good French translation" of this work in Baltimore, but, after a year, imported a copy from Amsterdam. The translation was under the direction of Malesherbes, with notes by a roster of well known men of science (de Sivry, de Querlon, Guetard and others, and astronomy notes by Bouguer and Lalande).

9. ARISTOTLE—CAMUS, ARMAND GASTON.
Histoire des Animaux d'Aristote, Paris: 1783. 4to. Two volumes.

A French translation of Aristotle's "History of Animals." Volume 1 has Greek and French texts on opposite pages. The title of Volume II is "Notes on Aristotle's History of Animals." Jefferson had the same experience with the purchase of this book as with number 8 above.

John Adams, wishing information on A. C. Camus, wrote to Jefferson, in 1815, who replied:

> "all I recalled of him is that he was one of the deputies sent to arrest Dumourier at the head of his army, who were however themselves arrested by Dumourier, and long detained as prisoners. I presume therefore he was a Jacobin. You will find his character in the most excellent revolutionary history of Toulongeon .... I believe also he may be the same person who has given us a translation of Aristotle's Natural history from the Greek into French ..." (Jefferson wrote the same year that François Emmanuel Toulongeon's "History of France since the Revolution of 1789" had given him "the first luminous view of the course of the French Revolution to the death of Robespierre, of which till then my ideas had been entirely chaotic.")

Armand Gaston Camus (1740–1804) was a philosopher and deputy to the French States General and National Convention.

10. LINNAEUS, CAROLUS.
Systema Naturae. Stockholm, 1766–1768, 12mo.

A work on classification of the three kingdoms of nature.

This is the twelfth edition of the 1735 work. Jefferson several times stated his opinion of the system of Linnaeus. For example, on February 22, 1814, he wrote to Dr. John Manners:

> ".... fortunately for science, he conceived in the three kingdoms of nature, modes of classification which obtained the approbation of the learned of all nations .... [his system] offered the three great desiderata
>
> 1. of aiding the memory to retain a knolege of the productions of nature.
>
> 2. of rallying all to the same names for the same objects, so that they could communicate understandingly on them and
>
> 3. of enabling them, when a subject was first presented, to trace it by its characters up to the conventional name by which it was agreed to be called .... I have not at all meant to insinuate that that of Linnaeus is intrinsically preferable to those of Blumenbach and Cuvier. I adhere to the Linnean because it is sufficient as a groundwork; admits of supplementary insertions, as new productions are discovered, and mainly because it has got into so general use that it will not be easy to displace it ...."

Carolus Linnaeus (1707–1778) was the famous Swedish scientist.

11. LINNAEUS, CAROLUS.
Mantissa Plantarum. Stockholm, 1771. 8vo.

This is a continuation of "Pars Prima" of the Mantissa Plantarum included in volume 2 of Systema Naturae. (number 10 above.)

12. LINNAEUS, CAROLUS GILBERT, JEAN EMMANUEL.
Abrégé du Système de la nature, Lyon: 1802. 8vo.

The abridged "System of Nature" by Linnaeus. This is a history of "mammals or quadrupeds and cetaceans," containing a free translation of the text of Linnaeus and Gmelin, an extract of the observations of Buffon, Brisson, Pallas and other celebrated zoologists, with a comparative anatomy of principal species, relative to quadrupeds and the most curious and useful cetaceans. Jefferson imported his copy from Amsterdam, after considerable effort to obtain it both from Baltimore and Bordeaux.

13. LINNAEUS, CAROLUS.
Fauna Svecica. Distributa per classes & ordines, genera & species, cum differentiis Specierum, Synononymis Auctorum, Nominibus Incolarum, Locis Natalium, Descriptionibus Insectorum. Editio altera, Auctior .... Stockholm: 1761. 8vo.

A classification of the animals of Sweden—with an ecological study of them.

14. BLUMENBACH, JOHANN FRIEDRICH.
Manuel d'Histoire Naturelle, Paris, 8vo. Two volumes.

This was a French translation by Soulaneg Artaud, (b. 1769) of the German work of J. F. Blumenbach (1752–1840) Professor at Gottingen, anthropologist, zoologist and physiologist.

There were translations in various other languages. In letters to his friends Jefferson wrote about Blumenbach's classification and nomenclature. To John Manners on February 22, 1814,

he expressed the view that disciples of Linnaeus, Blumenbach and Cuvier could no longer properly communicate with each other, and that their systems too, especially Blumenbach's, went too deeply into the province of anatomy.

15. CUVIER, GEORGES LÉOPOLD, BARON.
Tableau élémentaire de l'Histoire Naturelle des Animaux. Paris: 1798. 8vo.

Abridged course of lectures at the Ecole du Pantheon. Jefferson wrote (1802) on being notified by his bookdealer that a copy of this work was available:

> "... I shall be glad to receive the work of Cuvier. perhaps it may be the very one which I asked for the last year under the title of his Comparative anatomy, doubting whether that was the title, but it is enough that it is his & on anatomy...."

He discussed Cuvier's theories, nomenclature and system of classification with his scientific friends and referred to Cuvier frequently in his "Notes on the State of Virginia."

Georges L. Cuvier (1769–1832) was the famous French naturalist.

16. BUFFON, GEORGE LOUIS LECLERC, COMTE DE.
Histoire Naturelle des Oiseaux. Paris: 1770–1783. 4to. Ten volumes—five of text and five of color plates.

Jefferson must have esteemed this work on the natural history of birds, because he tried to obtain (1805) "the residue of the work .... ready bound: for otherwise binding here costs as much as the book...." He succeeded in obtaining it from Bordeaux, in 1806. His indifferent opinion of the author referred to earlier in this study, apparently did not reduce his respect for the writings on ornithology of the famous French naturalist George Louis Buffon, Comte de Buffon (1707–1788).

17. WILSON, ALEXANDER.
American Ornithology; or, The Natural History of the Birds of the United States: Illustrated with Plates Engraved and Colored from Original Drawings taken from Nature. Philadelphia: 1808–1814. Folio. Nine Volumes.

The last two volumes of this work were issued after Wilson's death. The work contains 76 plates of birds drawn and colored by Wilson. Jefferson was one of the original subscribers, but at the time he sold his library to Congress the last volume had not yet appeared. He wrote Wilson, on receiving a printed "Prospectus" that he wished:

> "to become a subscriber to it, satisfied it will give us valuable new matter as well as correct the errors of what we possessed before."

The cost was $12.00 per volume. By error he was billed a second time for three of these, but was able to establish that he had already paid for them.

Jefferson had written Wilson on April 7, 1805 that a certain bird

> "abounds in all the neighbourhoods of Philadelphia.... I have for 20 years interested the young sportsmen of my neighbourhood to shoot me one: but as yet without success."

Volume I page 32 contains an extract from this letter concealing Jefferson's authorships by the term

> "distinguished American gentleman to whom I had sent some drawings .... whose name would .... render any further observations on the subject from me unnecessary!

In Volume IV, page 75, concerning the description of the Magpie, Wilson says:

> "The drawing was taken from a very beautiful specimen sent from the Mandan nation, on the Missouri, to Mr. Jefferson and by that gentleman to Mr. Peale of this city, in whose museum it lived for several months ...."

Volume IX, (George Ord's life of Alexander Wilson) gives a quotation from Wilson's written request (February 6, 1806), to accompany Pike's expedition to the Mississippi as a naturalist. Although Jefferson had ample proof of Wilson's ornithological talents, he ignored the letter. Later he was to make a most remarkable defense of this attitude: To General James Wilkinson he wrote on June 25, 1818 that he had only a few days ago happened to see the posthumous volume of Wilson's Ornithology, where he read the "bitter invective" against him written by Ord for having

> "... refused to employ Wilson on Pike's expedition to the Arkansa on which particularly he wished to have been employed. on turning to my papers I have not a scrip of a pen on the subject of that expedition; which convinces me that it was not one of those which emanated from myself: and if a decaying memory does not deceive me I think that it was ordered by yourself from St. Louis, while Governor and military commander there...."

Jefferson continued to respect Wilson's works. On January 15, 1825, within two years of his death, he wrote his grandson-in-law, Joseph Coolidge, asking him to suggest to editors in Boston that they bring out an octavo edition of "the best of Wilson's Ornithology, giving plates of 8 vo. size also, with mere sketching of the forms of the birds in a light way."

Alexander Wilson (1766–1813) was born in Scotland and settled in Philadelphia, where he met and became a friend of William Bartram, botanist and naturalist.

George Ord (1781–1866), Philadelphia naturalist and philologist, accompanied his friend Wilson on many expeditions and brought out Volume IX after Wilson's death.

18. WILLUGHBY, FRANCIS.
The Ornithology of Francis Willughby of Middleton. In Three Books. Wherein All the Birds hitherto known, Being reduced into a Method suitable to their Natures, are accurately described. The Descriptions illustrated by most Elegant Figures, nearly resembling the live Birds. Translated into English, and enlarged with many Additions throughout the whole Work. To which are added, Three Considerable Discourses, I. of the art of Fowling: With a description of several Nets. II. Of the ordering of Singing Birds. III. Of Falconry. By John Ray, Fellow of the Royal Society . . . London: 1678, Folio.

This is a translation by John Ray, whose pupil, Francis Willughby, originally wrote the work in Latin:

Francis Willughby (1635–1672) was one of the original fellows of the Royal Society and the first naturalist to regard bird-study as a science. Linnaeus adopted his system of classification of birds.

19. BUFFON, GEORGE LOUIS LECLERC, COMTE DE
Histoire Naturelle, générale et particulière. Paris: 1752–1805. 12mo.

This is, collectively, a 71 volume work, the first 32 by Buffon and Daubenton, another 18 (on birds) by Buffon and Philibert Guéneau de Montbeillard, another 8 on reptiles, fishes, and cetaceans by de Lacépède after Buffon's death, and the remaining 13 (on mineralogy, etc.) by Buffon and other collaborators. It is not known how many of the 71 volumes Jefferson owned and finally sold to Congress.

Jefferson's "Notes on the State of Virginia" contains lengthy criticism of this work by Buffon. He wrote his friends that Buffon was

> "the great advocate of individualism, in opposition to classification."

20. (PISO, GULIELMUS, AND MARCGRAF, GEORG).
Historia Natvralis Brasiliae, Leyden and Amsterdam, 1648. Folio.

A Natural History of Brazil, with illustrations and descriptions of indigenous diseases, native customs, etc.

Gulielmus Piso (Willem Pison), 1611–1678, was a Dutch physician, naturalist, and the founder of Dutch Colonial medicine, who introduced the drug ipecac into European medicine. His contribution to this book consists of the first 122 pages, dealing with various medical matters (references to bubonic plague, etc.).

Georg Marcgraf (1610–1644) contributes a section giving an account of the inhabitants of Brazil.

21. GOLDSMITH, OLIVER.
An History of the Earth, and Animated Nature. Philadelphia, 1795, 8vo. Four volumes.

This is a posthumous work, first published in 1774, by the Irish poet and playwright (1728–1774).

22. CATESBY, MARK.
The Natural History of Carolina, Florida, and the Bahama Islands: Containing the figures of birds, beasts, fishes, serpents, insects, and plants: Particularly, those not hitherto described, or incorrectly figured by former authors, with their descriptions in English and French. To which is prefixed, a new and correct map of the countries; with observations on their natural state, inhabitants, and productions. 1771. Folio. Two volumes.

The text consists of English and French texts, in parallel columns.

Jefferson wrote that Catesby's History of Carolina had sold for ten guineas and that Francis Eppes should give that much

> ". . . . for Mr. Bollings' copy, if you can induce him to let me have it, which I am very anxious for. perhaps it would be a temptation to offer that the ten guineas should be paid to Mr. Ross's agents at Nantes, where he could lay them out and send the articles to Mr. Bolling. his draft shall be paid on sight in Paris. perhaps you had better effect this by making the proposition to Mrs.

Bolling. of this knowledge of the family will enable you to judge. . . ."

Jefferson's list of 93 birds in his "Notes on the State of Virginia" is accompanied by Linnaeus' and Catesby's designations, as well as popular names and Buffon references in parallel columns. He wrote of Catesby that "his drawings are better as to form and attitude than coloring, which is generally too high."

Mark Catesby (c.1679–1749) was an English naturalist who lived in America for a number of years.

23. BARTON, BENJAMIN SMITH.
Fragments of the Natural History of Pennsylvania. Philadelphia 1799. Folio.

This work contains only 21 leaves. A quotation from Jefferson's "Notes on the State of Virginia" reads:

> "Mr. Jefferson has observed that Perroquets even winter on the Sioto, in the 39th degree of latitude."

Benjamin Smith Barton (1766–1815) was a Philadelphia physician and naturalist, to whom Jefferson sent Captain Meriwether Lewis for "a note in the lines of" zoology, etc., before he set out on the famous expedition.

24. LACÉPÈDE, BERNARD GERMAIN, COMTE DE.
Histoire naturelle des quadrupedes, ovipares et des serpens. Paris: 1788–90. 12mo Four volumes.

These make up volumes 30 and 31 of Buffon's Histoire Naturelle and were written at his suggestion.

Bernard Germain Lacépède (1756–1825) was a French naturalist.

25. PENNANT, THOMAS.
History of Quadrupeds. London, 1793. 4to Two volumes.

Thomas Pennant (1726–1798) was an English traveller and naturalist.

26. VON ZIMMERMAN, EBERHARD.
Zoologie Géographique. (Translated by Jacques Mauvillon) from the Latin. Cassel: 1784. 8vo

In his General Geography, Horatio G. Spafford stated that the potato was indigenous to the United States. Jefferson wrote Spafford on May 14, 1809, that

> "Zimmerman, in his Geographical Zoology, says it is a native of Guiana."

Eberhard von Zimmerman (1743–1815) was a German naturalist and Professor of Natural History at Brunswick.

Jacques Mauvillon (1743–1794) was the son of a French professor of languages in Germany.

27. BONNET, CHARLES.
Oeuvres d'Histoire Naturelle et de Philosophie. Neuchatel: 1779–81. 8vo First twelve volumes of a set of eighteen.

Charles Bonnet (1720–1793) was a Swiss philosopher, naturalist, and a pioneer in experimental morphology.

28. REDI, FRANCESCO.
Esperienze intorno a Diverse Cose Natvrali, e particolarmente q qvelle, che ci son portate dall'Indie. Florence. 1671. 4to.

Experiments on various natural things, particularly those brought from the East and West Indies, including Brazilian tobacco.

Frescesco Redi (1626–1697) was the Italian naturalist and pioneer food analyst.

29. SPALLANZANI, LAZZARO.
Opuscoli di Fisicia Animale, e Vegetabile, Modena: 1780. 8vo. Four volumes.

A work on animal and vegetable physiology, consisting of two separate publications, and containing letters to the author. Jefferson wrote to Dr. Willard, on March 24, 1789 that Spallanzani's works:

> "on digestions and generation are valuable tho perhaps too minute, & therefore tedious, he has developed some useful truths, and his book is well worth attention."

Lazzaro Spallanzani (1729–1799) was the famous Italian pioneer in experimental morphology.

30. MOFFETT, THOMAS.
Insectorvm sive Minimorum Animalium Theatrvm: London: 1634. Folio

A work on entomology by Thomas Moffett, (1553–1604) English physician, with compilations from the works of Edward Wotton, Conrad Gesner and Thomas Penny. The 170 leaves contain over 500 woodcut illustrations of insects, including the first picture of an American butterfly in a printed book.

31. TYSON, EDWARD.
Orang-Outang, sive Homo Sylvestris: or, The Anatomy of a Pygmie compared with that of a Monkey, an Ape, and a Man, To which is added,

a Philological Essay concerning the Pygmies, the Cynocephali, the Satyrs, and Sphinges of the Ancients. Wherein it will appear that they are all either Apes or Monkeys, and not Men, as formerly pretended. London: 1699. Folio

Edward Tyson (1650–1708) was an Englishman and an early comparative anatomist. His pygmy was in reality a chimpanzee and the basis for the idea of the "missing-link." Its skeleton is in the South Kensington Museum in London.

32. ELLIS, JOHN.
The Natural History of many Curious and Uncommon Zoophytes, London: 1786. 4^{to}.

This work was published posthumously by Ellis's daughter, at the request of Sir Joseph Banks and was edited by Ellis's friend Daniel C. Solander, Swedish botanist, who was for a time in charge of the department of Natural History in the British Museum.

33. BAKER, HENRY.
An Attempt towards a Natural History of the Polype: London: 1743. 8^{vo}.

Henry Baker and Martin Folkes began a series of studies on the Polyphus which were later continued by Baker alone and first published in the "Philosophical Transactions." The work includes "great numbers of proper figures and a variety of observations and experiments."

Henry Baker (1698–1774), English naturalist, poet, and fellow of the Royal Society was responsible for the introduction of the rhubarb plant into England.

Martin Folkes (1690–1754) was an English scientist, and President of the Royal Society.

34. BAKER, HENRY.
The Microscope made easy: or I. The Nature, Uses, and Magnifying Powers of the best Kinds of Microscopes described, calculated, and explained . . . II. An Account of what surprizing Discoveries have been already made by the Microscope . . . And also a great Variety of new Experiments and Observations, pointing out many uncommon Subjects for the Examination of the Curious. By Henry Baker . . . London: 1744. 8^{vo}.

The book has a plate on the Solar Microscope and a further account of the Polype.
(see number 33 above)

35. ADAMS, GEORGE.
Micrographia Illustrata: or the Microscope explained, in several new Inventions, particularly of a new Variable Microscope for examining all sorts of minute objects; and also of a new Camera Obscure Microscope . . . with a Description of all the other Microscopes now in use. Likewise a Natural History of Aerial, Terrestrial, and Aquatic Animals, &c. considered as microscopic objects. London: 1771. 8^{vo}.

The book contains "560 delineations of various microscopic objects," and was frequently reprinted from the first edition. Jefferson's was the fourth edition.

George Adams (1720–1773) was a mathematical instrument maker to George III.

36. FONTANA, FELICE.
Richerche fisiche sopra il veleno della vipera, Lucca: 1767. 8^{vo}.

The results of the author's researches on the poison of the viper, to which is added certain other observations, both works bound together.

Felice Fontana (1730–1805) was an Italian naturalist, physiologist, and early investigator of viper venom, whose works influenced modern study in this field.

37. PALFYN, JEAN.
Description anatomique des Parties de la Femme, qui servent à la Generation; avec un Traité des Monstres, de leur Nature, & de leur differences . . . Leyden. 1708. 4^{to}.

This treatise on the female reproductive organs also deals with the cause and nature of malformed births. In addition it contains writings by François Mauriceau on obstetrics.

Jean Palfyn (1650–1730) was a Belgian anatomist, surgeon, and pioneer in "anatomical surgery."

François Mauriceau (1637–1709) was a French obstetrician and surgeon.

38. BARRINGTON, DAINES.
Miscellanies. London: 1781. 4^{to}.

There is an interesting reference by Jefferson, to Barrington's Essay I:

> "Whether the Turkey was known before the Discovery of America."

On January 10, 1801, he wrote to Dr. Hugh Williamson

> ". . . . I suppose the opinion to be universal that the Turkey is a native of America, nobody, as far as I know, has ever contradicted it but Daines Barrington: and the arguments he produces are such as none but a head,

entangled & kinked as his is, would ever have urged. . . ."

Daines Barrington (1727–1880) was an English lawyer and naturalist.

39. ZOOLOGY TRACTS (8vo.)

i. LACÉPÈDE, BERNARD GERMAIN COMTE DE. Discours d'ouverture et de clôture du Cours de Zoologie donné dans le Museum national d'Histoire naturelle, Paris: (1801).

ii. GUIDE TO THE PHILADELPHIA MUSEUM

iii. PEALE, REMBRANDT.
Account of the Skeleton of the Mammoth, a non-descript carnivorous Animal of immense size, found in America. London: 1802.

iv. PEALE, REMBRANDT
An Historical Disquisition on the Mammoth, or Great American Incognitum . . . London: 1803.

i. Lacépède's tract is a printing of the addresses which opened and closed the zoology course at the National Museum of Natural History, and is a presentation copy by the author. Jefferson wrote him on February 24, 1803, that:

> ". . . . a rapid view of parts of it only assures me of the pleasure that I shall receive from a deliberate perusal of the whole the first moment I have to spare. I was struck with the prophetic spirit of the passage [that courageous explorers would soon travel to the sources of the Mississippi and the Missouri, etc.]. it happens that we are now actually sending off a small party to explore the Missouri to it's source. . . . it is not improbable that this voyage of discovery [Lewis and Clark] will procure us further information of the Mammoth, & of the Megatherium also, mentioned by your page 6. . . . before we had seen the account of that animal by Mr. Cuvier, we had found here some remains of an enormous animal incognitum, whom, from the disproportionate length of his claw, we had denominated Megalonyx, and which is probably the same animal. . . . I thank you . . . . for the occasion it [Lacépède's address] has given me of turning for a moment from the barren field of politics to the rich map of nature. . . ."

ii. The "Guide to the Philadelphia Museum" was probably a gift from his friend, Charles Willson Peale, artist and founder of the museum.[4]

iii. Rembrandt Peale was proprietor of a museum in London, where his father, Charles Willson Peale, sent him and his brother, Rubens, in 1801, to exhibit one of the two skeletons of the mammoth or mastodon which their father had recovered near New York. The war with France caused the return of the brothers in 1803.

iv. This is a revision of iii. Both iii and iv give an account of the skeleton exhibited in London and were presentation copies from Charles Willson Peale, father of the author of both tracts.

Rembrandt Peale (1778–1860) was a portrait and historical painter.

40. TRACTS IN ZOOLOGY.

i. DEBURE DE SAINT-FAUXBIN, JEAN FRANÇOIS. *Lettres d'un Solitaire à un academicien de province sur la la nouvelle version françoise (par Camus) de l'Histoire des Animaux d'Aristote.* Amsterdam and Paris: 1784, 4to.

ii. SPALLANZANI, LAZZARO.
Lettera apologetica in risposta alle osservazioni sulla digestione del sig. Giovanni Hunter. Milano: 1788. 8vo.

These tracts were originally bound together in one volume. The first deals with Camus's translation of Aristotle's History of Animals (see number 9 above). The second is a letter, replying to John Hunter, on digestion.

Jean F. D. de Saint-Fauxbin (1741–1825) was a French hellenist.

41. LACÉPÈDE, BERNARD, COMTE DE.
Histoire Naturelle des Poissons, Paris 1798, Five Volumes. 4to.

Jefferson sold to Congress only five of the six volumes in this set. The first five, on the natural history of fish, and the last or sixth, on the natural history of cetaceans, were presentation copies from the author who expressed his very high admiration and esteem of Jefferson.

> "It is with pleasure I embrace this occasion of returning you my thanks for the favor of your very valuable works sur la poissons et les cetaceés . . . . which I find entirely worthy of your high reputation in the literary world. . . ." Jefferson wrote him on July 14, 1808.

This work was published in connection with Buffon's Natural History, (see numbers 19 and 24 above.)

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[4] Jefferson was for a time president of the board of trustees of Peale's Philadelphia Museum which had the first public exhibition of fossil vertebrates and the first mounted fossil skeleton in our country.

42. VIREY, JULIEN JOSEPH.
Histoire Naturelle du Genre Humain, ou Recherches sur ses principaux Fondemens physiques et moraux; précédées d'un Discours sur la nature des etres organiques, et sur l'ensemble de leur physiologie. On y a joint une dissertation sur le sauvage de l'Aveyron. Paris: (1801) 8vo. Two Volumes.

The natural history of mankind, or researches on the chief foundations of body and mind, preceded by a discourse on the nature and physiology of organic beings, to which is added a dissertation on the savage of Aveyron.

The author used Jefferson's "Notes on the State of Virginia" as one of his source books. Virey's footnotes make acknowledgment of Jefferson as one of the principal authors cited.

Julien J. Virey (1775–1846) was a French physician, scientist, and Professor (Faculty of Paris).

43. WALCKENAER, CHARLES ATHANASE, BARON.
Tableau des Aranéides, ou Caractères essentiels des tribus, genres, familles et races que renferme le genre Aranea de Linné, avec la désignation des espèces comprises dans chacune de ces divisions. Paris: 1805. 8vo.

This is work on venomous spiders, dealing with the essential characteristics of the divisions which make up the Aranea, with the names of the species included in these divisions.

Charles A., Baron Walckenaer (1771–1852) was a French naturalist.

Jefferson also owned:

Histoire naturelle de Mavor.
Plinii historia naturalis.
Promenades au jardin des plantes.
Transactions of the Linneaen Society.
Turton's translation of the Linnaean system of nature.

Jefferson's "1815 library" also contained the following books of a zoological character, although classified by him under different headings.

Natural Philosophy: Tracts

1. "A Memoir concerning. . . . the Rattlesnake and other American serpents." Benjamin Smith Barton
2. "Megatherium", in The Monthly Magazine, September, 1796. (A notice drawn up by Cuvier)

Agriculture

"Proceedings. . . respecting an insect supposed to infest wheat of the territories of the United States," [Hessian fly]. Arthur Young

The Jefferson "library of 1829," referred to earlier in this study, contained the following books, in whole or part on zoology:

Histoire des Animaux d'Aristote, Camus, 2 vols. 4to.
North American Sylva, Michaux. 3 vols. in two. 8vo.
Pamphlets in Natural History. Barton, Parker, Table of Mountains, Observer, 8vo.
Natural History, Peyroux, Hosack, Cels, Raffinesque, Clinton, Serpent, Humboldt, Bigelow, Clinton, McCulloch, Cooper, Meleze, Maclure, 8vo.
Zoological Pamplets, Cuvier, Barton.
Journal of Academy of Sciences of Philadelphia, 8vo.
Natural History, 1817–20, to wit: Silliman, Academy Natural Sciences, Lyceum of New York, Raffinesque, 8vo.
Natural History and Resources of New York, Hibernicus, 1822.
Fauna Americana, Harlan, 8vo.
Anatomy, Wistar, 2 vols. 8vo.

Jefferson was interested in all of the sciences, but he lacked the time necessary to be anything more than an enthusiastic and intelligent amateur. His great prestige as statesman and President served to make his enthusiasm contagious and encouraging to others, and made the American people conscious of the value of science. In the field of paleontology however, he not only became an independent investigator but also lent a dignity and honor which helped its advance. He may even have been motivated by the possible utilitarian aspect of this science, hoping that its findings might be of value in human betterment. Unfortunately his enthusiasm made him the victim of ridicule as an atheist and a wanton, who was neglecting his duties, so that William Cullen Byrant at the age of 13 years wrote (and later did his best to suppress) the following poem:

"The Embargo

Go wretch, resign thy presidential chair,
Disclose thy secret measures, foul or fair
Go, search with curious eye for horned frogs,
Mid the wild wastes of Louisianian bogs;
Or where the Ohio rolls his turbid stream
Dig for huge bones, thy glory and thy theme."

His interests took him into other sciences as a pioneer—botany, ethnology and geography among them, and in all of them he strove for accuracy and truth. Writings abound in high praise of his attainment, literary as well as scientific. La Rochefoucauld wrote that Jefferson possessed

> "a stock of information not inferior to that of any other man."

Benjamin Smith Barton gave it as his opinion that

> "especially in botany and zoology the information of this gentleman is equalled by that of few persons in the United States."

Such was the rank held by the "Great Patriarch of American Natural History."

LITERATURE CITED

BROWNE, CHARLES A. 1944. Thomas Jefferson and the Scientific Trends of his Time. Chronica Botanica **8**: 3.

CLARK, AUSTIN H. 1943. Thomas Jefferson and Science. Jour. of the Washington Acad. of Sci. **33**: 7.

OLIVER, J. W. 1943. Thomas Jefferson, Scientist. Sci. Monthly **56**: 460–467.

SOWERBY, E. MILLICENT. 1952. Catalogue of the Library of Thomas Jefferson. Library of Congress.

SOME FURTHER METHODS IN ALGEBRAIC CRYPTOGRAPHY

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1. *Introduction.* In a previous paper, [3], the author has presented several methods of algebraic encipherment which have the property of providing a variable substitute for any given sequence of n letters. This was accomplished through a matrix transformation, the matrix being defined in terms of one or more parameters, these providing the means for the variable substitutions.

In this paper we discuss two new methods of this kind of encipherment. While the transformations involved were not intended to be primarily of the matrix types, it is a matter of interest that they may be so considered. This will be shown below.

2. *Some General Considerations.* One object of algebraic cryptography is to find methods of encipherment based on mathematical operations. The best known of these, and one of great generality, is that of matrix multiplication, (see [1], [2], [3]). By this method a sequence of n plain-text letters is converted into a sequence of n cipher-text letters through the matrix congruence

$$C \equiv AP \pmod{26}, \tag{1}$$

where $A = [a_{ij}]$ is an $n \times n$ matrix; C and P are one-column matrices (vectors),

$$C = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{bmatrix}, \qquad P = \begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_n \end{bmatrix}. \tag{2}$$

The components $p_1, p_2, \cdots, p_n$ of vector $P(p_1, \cdots, p_n)$ are the n numbers representing numerical values of the n plain-text letters according to some 1–1 reciprocal correspondence between the 26 letters of the alphabet, and the 26 numbers 0, 1, 2, $\cdots$, 25.

Likewise, $c_1, \cdots, c_n$ represent the numerical values of the n cipher letters as determined from (1) and this correspondence. The elements a_{ij} of matrix A are also integers from the range 0, 1, 2, $\cdots$, 25.

To obtain a unique decipherment, the determinant $|A|$ of A must be prime to 26, whence $P \equiv A^{-1}C$ will produce the plain-text.

A rather general formulation of the problem under consideration can be made in this way:

Given an ordered sequence of vectors $P_1, P_2, P_3, \cdots$, to find transformations T converting P_i to a vector $C_i = T(P_i)$, $(i = 1, 2, 3, \cdots)$. The transformation T is to have the properties:

(a) For any value of i a unique inverse T^{-1} must exist, so that $P_i = T^{-1}(C_i)$,

(b) If two of the vectors P_i, P_j are identical, the corresponding transforms C_i, C_j are not necessarily identical,

(c) The components of any vector $P_i(p_1, p_2, \cdots, p_n)$ being integers in the range 0, 1, 2, $\cdots$, 25, a similar statement must be true of the transform components $C_i(c_1, c_2, \cdots, c_n)$.

The matrix transformations of [3] satisfy these conditions. We turn now to the new methods of transformation mentioned above.

3. *Method of polynomial division.* The plain-text letters are grouped in sets of n letters and converted to numerical form by a correspondence as mentioned in section 2. Let $p_1, p_2, \cdots, p_n$ be any one such converted group. Now form the identity congruence

$$\frac{p_1x^{n-1} + p_2x^{n-2} + \cdots + p_{n-1}x + p_n}{a_1x^{k-1} + a_2x^{k-2} + \cdots + a_{k-1}x + a_k}$$

$$\equiv q_1x^{n-k} + q_2x^{n-k-1} + \cdots + q_{n-k+1} \tag{3}$$

$$+ \frac{r_1x^{k-2} + r_2x^{k-3} + \cdots + r_{k-1}}{a_1x^{k-1} + \cdots + a_k}, \pmod{26}.$$

In (3), $k \leq n$; $a_1, a_2, \cdots, a_k$ are arbitrary integers with a_1 prime to 26. (This a-sequence is to vary from one group to the next in some preassigned manner.) The quotient and remainder coefficients in some preassigned order are taken to be the cipher values $c_1, c_2, \cdots, c_n$ of the n cipher letters corresponding to the n plain letters.

To decipher, we consider (3) in the equivalent form

$$p_1x^{n-1} + \cdots + p_n \equiv (a_1x^{k-1} + \cdots + a_k)$$

$$(q_1x^{n-k} + \cdots + q_{n-k+1}) + r_1x^{k-2} \tag{4}$$

$$+ \cdots + r_{k-1}, \pmod{26},$$

carry out the indicated multiplications and additions on the right side, and thus determine $p_1, \cdots, p_n$, and hence the plain letters. (Since n and k are known it is of course easy to distinguish between the quotient coefficients q and the remainder coefficients r in the set $c_1c_2 \cdots c_n$.)

All operations in both (3) and (4) can be performed rapidly using detached coefficients and a multiplication table modulus 26. Such a table lists all products $c \equiv ab$, mod 26 ($a, b \leq 25$).

An example will explain the details of the procedure. Example. To encipher the plain-text

SYNTHETIC DIVISION,

using the correspondence

(5)

A	B	C	D	E	F	G	H	I	J	K	L	M
1	2	3	4	5	6	7	8	9	10	11	12	13

N	O	P	Q	R	S	T	U	V	W	X	Y	Z
14	15	16	17	18	19	20	21	22	23	24	25	0

Use $n = 5$, and divide the text in groups of 5 letters:

(6)

S	Y	N	T	H		E	T	I	C	D
19	25	14	20	8		5	20	9	3	4

I	V	I	S	I		O	N	X	Y	Z
9	22	9	19	9		15	14	24	25	0

(XYZ added to complete the last group).

To determine sequences of coefficients a_1, $a_2, \cdots$ in (3) which vary from one group of (6) to the next, first choose a basic key-sequence, say

(7) 5 8 19 6 12 17.

This is expanded into a longer sequence by repeating its elements in a cyclic manner, and then grouping the resulting numbers in lengths indicated by a secondary key-sequence, say 4, 2, 3, 5. This would give

(8)

(4)	(2)	(3)	(5)
5 8 19 6	12 17	5 8 19	6 12 17 5 8

(4)	(2)	(3)	..
19 6 12 17	5 8	19 6 12	...

The various groups in (8) constitute the coefficients a_i to be used in (3). The encipherment of the first group of (6) proceeds then:

19 25 14 20 8	5 8 19 6
19 20 15 2	9 1
5 25 18 8	
5 8 19 6	
17 25 2	

All calculations are performed modulus 26. The first division $19/5 = (1/5)(19) \equiv (21)(19) \equiv 9$, (as $5 \cdot 21 \equiv 1$).

The quotient and remainder coefficients 9, 1, 17, 25, 2 in this order yield by (5) the cipher group I A Q Y B as the encipherment of the first plain group S Y N T H.

To encipher the second group the divisor coefficients $a_1a_2 = 12\ 17$ must be used. Since $a_1 = 12$ is not prime to 26 we adopt the convention of using the next higher prime, 15, to give a_1. The calculations are

5 20 9 3 4	15 17
5 23	9 5 14 19
23 9	
23 7	
2 3	
2 4	
25 4	
25 11	
19	

This gives 9, 5, 14, 19, 19 or I E N S S, the second cipher group. The complete encipherment is IAQYB IENSS GNJKA QRURT.

Decipherment is by means of (4). Since k and the coefficients $a_1, \cdots, a_k$ are known in every case it is easy to separate the q_i and r_i coefficients. Thus, to decipher the first group A I Q Y B = 9 1 17 25 2, we know $k = 4$, $a_1a_2a_3a_4 = 5\ 8\ 19\ 6$; hence there must be $n - k + 1 = 2$ q-coefficients, 9, 1; and $k - 1 = 3$ r-coefficients, 17 25 2. This gives, from (4)

5 8 19 6	
9 1	
19 20 15 2	
5 8 19 6	
19 25 23 21 6	
17 25 2	
19 25 14 20 8	
S Y N T H	= first plain group.

From (4) it is easy to obtain the matrix relation

$$\begin{bmatrix} p_1 \\ p_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ p_n \end{bmatrix} \equiv \begin{bmatrix} a_1 & & & & & & \\ a_2 & a_1 & & & & & \\ \cdot & \cdot & \cdot & & & & \\ \cdot & \cdot & \cdot & a_1 & & & \\ a_k & \cdot & & \cdot & 1 & & \\ & a_k & & \cdot & & \cdot & \\ & & & \cdot & & & \cdot \\ & & & a_k & & & 1 \end{bmatrix}$$

$$\cdot \begin{bmatrix} c_1 \\ c_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ c_n \end{bmatrix}, \pmod{26}. \tag{9}$$

The first $n - k + 1$ columns of the triangular matrix contain the sequence $a_1a_2 \cdots a_k$, beginning with a_1 on the main diagonal. The last $k - 1$ columns contain only 1's, and these on the main diagonal.

The triangular property of this matrix constitutes a cryptographic weakness which the cryptanalyst would be quick to use. This weakness can to a great extent be eliminated in a large variety of ways, one of which is to vary the order of writing the quotient and remainder coefficients. (In the above example this order was fixed throughout the encipherment.) However, since it is not our purpose to treat this phase of the subject here, we refrain from further remarks along this line.

4. *Method of Synthetic Division Algorithm.* By this method we encipher a plain group $p_1p_2 \cdots p_n$ to $c_1c_2 \cdots c_n$ by means of the transformation

$$\begin{aligned} ax^n + p_1x^{n-1} + p_2x^{n-2} + \cdots + p_{n-1}x + p_n \\ \equiv a(x-h)^n + c_1(x-h)^{n-1} + c_2(x-h)^{n-2} \\ + \cdots + c_{n-1}(x-h) + c_n, \pmod{26}. \end{aligned} \tag{10}$$

In this identity congruence a and h are two numbers selected in advance. To obtain the coefficients c_i we use the well-known process of continued synthetic division. The following example illustrates the method.

Example. To encipher

SYNTHETIC DIVISION APPLICATION

using $n = 5$, $a = 1$, $h = 12$ throughout the encipherment. Divide the plain-text in groups of 5 and convert letters to numbers by the correspondence (5),

S	Y	N	T	H		E	T	I	C	D
19	25	14	20	8		5	20	9	3	4

I	V	I	S	I		O	N	A	P	P
9	22	9	19	9		15	14	1	16	16

L	I	C	A	T		I	O	N	X	X
12	9	3	1	20		9	15	14	24	24

The first group 19 25 14 20 8, with $a = 1$ gives the polynomial $x^5 + 19x^4 + 25x^3 + 14x^2 + 20x + 8$. We divide this by $x - 12$, ($h = 12$), using mod 26 calculations,

1	19	25	14	20	8	[12]
	12	8	6	6	0	
1	5	7	20	0	[8]	
	12	22	10	22		
1	17	3	4	[22]		
	12	10	0			
1	3	13	[4]			
	12	24				
1	15	[11]				
	12					
1	[1]					

giving 1 11 4 22 8 = $c_1c_2c_3c_4c_5$ = A K D V H as the first cipher group. The remaining cipher groups are obtained in a like manner, the final result being AKDVH MJUQT QVMWK WPMNN TWYEX QOZJT.

To decipher the first group AKDVH, convert to numbers and divide by $x - 14$ (since $-12 \equiv 14$),

1	1	11	4	22	8	[14]
	14	2	0	4	0	
1	15	13	4	0	[8]	
	14	16	16	20		
1	3	3	20	[20]		
	14	4	20			
1	17	7	[14]			
	14	18				
1	5	[25]				
	14					
1	[19]					

giving 19 25 14 20 8 = S Y N T H, the first plain group, etc.

In decipherment, of course, the division is always by $x + h$, or by $-h \equiv 26 - h$, synthetically.

From (10) or the equivalent

$$\begin{aligned} &ay^n + c_1y^{n-1} + c_2y^{n-2} + \cdots + c_{n-1}y + c_n \\ &\equiv a(y+h)^n + p_1(y+h)^{n-1} + p_2(y+h)^{n-2} \\ &\quad + \cdots + p_{n-1}(y+h) + p_n, \pmod{26}, \end{aligned} \tag{11}$$

it is not difficult to obtain the matrix relations

$$\begin{bmatrix} c_1 \\ c_2 \\ \cdot \\ \cdot \\ \cdot \\ c_n \end{bmatrix} \equiv \begin{bmatrix} 1 & & & \\ \binom{n-1}{1}h & 1 & & \\ \binom{n-1}{2}h^2 & \binom{n-2}{1}h & 1 & \\ \cdot & \cdot & & \\ \cdot & \cdot & & \\ \cdot & \cdot & & \\ \binom{n-1}{n-1}h^{n-1} & \binom{n-2}{n-2}h^{n-2} & \cdots & 1 \end{bmatrix} \tag{12}$$

$$\begin{bmatrix} p_1 \\ p_2 \\ \cdot \\ \cdot \\ \cdot \\ p_n \end{bmatrix} + a \begin{bmatrix} \binom{n}{1}h \\ \binom{n}{2}h^2 \\ \cdot \\ \cdot \\ \cdot \\ \binom{n}{n}h^n \end{bmatrix}, \pmod{26}$$

or

$$C \equiv A(h)P + aB(h), \pmod{26} \tag{13}$$

where matrix $A(h)$ is a triangular matrix whose elements in its column m are the successive terms in the expansion of $(1 + h)^{n-m}$ with the 1 on the main diagonal, and $B(h)$ is a column vector as shown.

If $n = 4$, (12) would be

$$\begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \end{bmatrix} \equiv \begin{bmatrix} 1 & 0 & 0 & 0 \\ 3h & 1 & 0 & 0 \\ 3h^2 & 2h & 1 & 0 \\ h^3 & h^2 & h & 1 \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \end{bmatrix} + a \begin{bmatrix} 4h \\ 6h^2 \\ 4h^3 \\ h^4 \end{bmatrix}. \tag{14}$$

The inverse to (12) or (13) is easily written down as

$$P \equiv A(-h)C + aB(-h). \tag{15}$$

On solving (13) formally for P and comparing with (15) there is obtained the interesting matrix relations

$$\begin{aligned} A(-h) &= A^{-1}(h), \\ B(-h) &= -A^{-1}(h)B(h). \end{aligned} \tag{16}$$

The fact that corresponding plain and cipher values are related through a triangular matrix by (13) repeats the situation of the first method in the previous section. To offset this apparent fault, the following variations are suggested, these strengthening the cryptographic result.

(A) Use a different h and a from one plain group to the next (n fixed),

(B) Vary all three, a, h, and n from group to group.

(C) Perform a rearrangement of the cipher letters within each group after encipherment by the division algorithm (using (A) or (B) in addition).

(D) Use the polynomial

$$ax^n + a_1p_1x^{n-1} + a_2p_2x^{n-2} + \cdots + a_{n-1}p_{n-1}x + a_np_n$$

in (10), where the a_i are prime to 26 (but kept fixed from group to group.

Of course, many other variations are possible.

LITERATURE CITED

HILL, L. S. 1929. Cryptography in an algebraic alphabet. American Mathematical Monthly **36:** 306–312.

———. 1931. Concerning certain linear transformation apparatus of cryptography. Amer. Math. Monthly **38:** 135–154.

LEVINE, J. 1958. Variable matrix substitution in algebraic cryptography. Amer. Math. Monthly **65:** 170–179.

EQUIVALENT NONLINEAR PROBLEMS*

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The reader can quickly get the main idea of this paper by simple analogy. In the study of linear boundary value problems, one frequently makes use of an equivalence between homogeneous differential equations with nonhomogeneous boundary conditions and nonhomogeneous differential equations with homogeneous boundary conditions [1]. By this equivalence, one knows that when he has solved a boundary value problem of one of these two classes, his solution also satisfies the corresponding problem in the other class. The purpose of this paper is to establish special cases of the same kind of equivalence where the adjective "homogeneous" is replaced by "linear," and, of course, "nonhomogeneous" is replaced by "nonlinear." The advantage of this equivalence is that it enables us to "get two for the price of one," so to speak, in solving nonlinear problems, and since the price of solving these problems is usually quite high, the advantage is worth noting wherever it can be had.

Let us begin with one class of nonlinear problems which have been solved, namely

$$U_t = U_{xx} \qquad t > 0, x > 0 \tag{1}$$

$$U(x, 0) = 0 \qquad x > 0 \tag{1a}$$

$$U_x(0, t) = -G[U(0, t)] \qquad t > 0 \tag{1b}$$

$$| U(x, t) | < M \qquad x \geq 0, t \geq 0 \tag{1c}$$

where the class of admissible G's consists of all those continuous decreasing functions for which $G[U_0] = 0$ for some $U_0 > 0$. This problem, which we shall refer to as problem (1), has been extensively treated ([2], [3]). It is known to have a unique solution, $U(x, t)$, which is bounded between 0 and U_0, which is an increasing function of t for all x, and for which $\lim_{t\to\infty} U(x, t) = U_0$ for all x. Furthermore, when G satisfies a Lipschitz condition, U can be approximated by a convergent iterative process in which the iterates are alternately too big and too little, so that a good upper bound for the error at any stage is easy to get.

Let us now make a change in the dependent variable in problem (1) by the following substitution

$$U(x, t) = F[V(x, t)] \tag{2}$$

where F is some function which is at least almost everywhere twice differentiable, and which is yet to be determined. It is easily seen that V must be a solution of

$$F'[V] \cdot V_t = F'[V] \cdot V_{xx} + F''[V] V_x^2$$

$$F[V(x, 0)] = 0$$

$$F'[V(0, t)] \cdot V_x(0, t) = -G\{F[V(0, t)]\}$$

$$| F[V(x, t)] | < M$$

At this point we must decide just what kind of linear boundary condition we should like to have replace the nonlinear condition (1b). The one which naturally suggests itself is that one which is generally assumed in diffusion problems of this sort, namely, Newton's Law of Cooling. This means that we should try to find an F with nonvanishing derivative which satisfies

$$-\frac{G\{F[V]\}}{F'[V]} = -h[U_0 - V] \qquad (h > 0)$$

This will be true if

$$\frac{dF}{dV} = \frac{G\{F[V]\}}{h[U_0 - V]} \tag{3}$$

Since G is monotone, G' exists almost everywhere, and since we have required of F that it be almost everywhere twice differentiable, (3) implies that, almost everywhere,

$$\frac{d^2F}{dV^2} = \frac{h[U_0 - V]G' \cdot F' + G \cdot h}{h^2(U_0 - V)^2}$$

This together with (3) reduces to

$$\frac{d^2F}{dV^2} = G[F(V)] \frac{G'[F] + h}{h^2[U_0 - V]^2}$$

Dividing both sides by F' and using (3) again gives

$$\frac{F''}{F'} = \frac{G'[F] + h}{h[U_0 - V]}$$

* This work was sponsored by the U. S. Air Force, Contract Number AF 18 (600)-1139.

almost everywhere. Thus far we have shown that if there exists an F which will linearize (1b) in the desired way, then $V(x, t)$ must satisfy

$$V_t = V_{xx} + \left[\frac{G'[F(V)] + h}{h(U_0 - V)}\right] \cdot V_x^2$$

$$F[V(x,0)] = 0$$

$$V_x(0,t) = -h[U_0 - V(0,t)]$$

$$|F[V(x,t)]| > M$$

This problem will become more interesting if we can choose an admissible G in such a way that the coefficient of V_x^2 is simpler—say for example a constant. A convenient choice for a constant is $\frac{1}{U_0}$. This choice leads to the requirement that

$$\frac{G'[F] + h}{h[U_0 - V]} = \frac{1}{U_0},$$

at least almost everywhere, and this simplifies to

$$G'[F] = -\frac{h}{U_0} V$$

The success of our enterprise now depends upon being able to find a suitable F and an admissible G so that at least a. e. the two following equations are satisfied simultaneously:

$$\frac{dF}{dV} = \frac{G[F(V)]}{h(U_0 - V)} \tag{3}$$

$$\frac{dG}{dF} = -\frac{h}{U_0} V \tag{4}$$

Differentiating (3) with respect to V and then simplifying the resulting expression with the help of both (3) and (4), we get

$$\frac{d^2F}{dV^2} = \frac{G[F(V)]}{hU_0(U_0 - V)} = \frac{1}{U_0}\frac{dF}{dV}$$

The equation $F'' = \frac{1}{U_0} F'$ is satisfied everywhere by $F = Ke^{V/U_0} + B$. In choosing the constants of integration we are motivated by the observation that boundary condition (1a) can be kept the same for V as for U by the simple expedient of requiring that $F(0) = 0$. This leads to $B = -K$ and

$$F = K(e^{V/U_0} - 1) = U. \tag{5}$$

This is obviously a monotone function with the following unique inverse

$$V(x,t) = U_0 \log\left[1 + \frac{U(x,t)}{K}\right] \tag{6}$$

We now turn our attention to the problem of finding G, hoping that the problem has an admissible solution. From (3), (5) and (6) we quickly see that

$$G[F] = h(F + K)\left[1 - \log\left(1 + \frac{F}{K}\right)\right]$$

Since U is known to satisfy the inequalities $0 < U(x,t) < U_0$, and $h > 0$, it follows from (4) that G is a decreasing function. We can get $G[U_0] = 0$ by taking $K = U_0(e - 1)^{-1}$, and therefore an admissible G does exist to go with our previously found F. The final determinations are

$$U(x,t) = F[V(x,t)] = U_0(e-1)^{-1}(e^{[V(x,t)]/U_0} - 1) \tag{7}$$

$$G[U(0,t)] = h[U(0,t) + U_0(e-1)^{-1}] \cdot \left[1 - \log\left\{1 + (e-1)\frac{U,(0,t)}{U_0}\right\}\right], \tag{8}$$

$$V(x,t) = U_0 \log\left[1 + (e-1)\frac{U(x,t)}{U_0}\right] \tag{9}$$

We have proved that if $U(x, t)$ is the solution of Problem I defined as follows:

I
$$U_t(x,t) = U_{xx}(x,t) \qquad x > 0, t > 0$$
$$U(x,0) = 0 \qquad x > 0$$
$$U_x(0,t) = -h[U(0,t) + (e-1)^{-1}U_0] \cdot \left[1 - \log\left\{1 + (e-1)\frac{U(0,t)}{U_0}\right\}\right]$$
$$|U(x,t)| < M \qquad x \geq 0, t \geq 0,$$

then $V(x, t)$ defined by (9) satisfies Problem II below

II
$$V_t = V_{xx} + \frac{1}{U_0} V_x^2$$
$$V(x,0) = 0$$
$$V_x(0,t) = -h[U_0 - V(0,t)]$$
$$|V(x,t)| < U_0 \log\left[1 + (e-1)\frac{M}{U_0}\right]$$

The converse is also easy to prove, namely, if $V(x, t)$ satisfies Problem II, then $U(x, t)$ as given by (7) satisfies (I). From what is known about Problem (I), we can announce the following results for Problem II: Problem II has a unique

solution $V(x, t)$; $V(x, 0) = 0$; $V(x, t)$ is an increasing function of t for all x; and $\lim_{t\to\infty} V(x, t) = U_0$ for all x. Furthermore, it is easy to see from (8) that G does satisfy a Lipschitz condition on every finite positive interval, and from this one can infer that the method of successive approximations described in [2] and [4] is applicable to solve (I) and therefore (II) also.

In conclusion we mention a class of nonlinear elliptic problems similar to Problem (I) for which some results have been obtained, namely

$$\text{III}\quad \begin{aligned} &U_{xx} + U_{yy} = 0 && 0 < x < \pi, 0 < y < \infty \\ &U(0, y) = U(\pi, y) = 0 && 0 \le y < \infty \\ &U_y(x, 0) = -G[U(x, 0)] && 0 < x < \pi \\ &|\, U(x, y)\,| < M && 0 \le x \le \pi, 0 \le y < \infty \end{aligned}$$

where the class of admissible G's is the same as in problem (1). It has been proved [4] that this problem has a unique solution which is bounded between 0 and U_0 and which can be approximated by a convergent iterative process having the same desirable characteristic as that described for problem (1), when G satisfies a Lipschitz condition. Steps similar to those we have already gone thru show that if $U(x, t)$ is the solution of III, where G is given by (8), then $V(x, t)$ given by (9) satisfies Problem IV, i. e.

$$\text{IV}\quad \begin{aligned} &V_{xx} + V_{yy} + \frac{1}{U_0}(V_x^2 + V_y^2) = 0 \\ &V(0, y) = V(\pi, y) = 0 \\ &V_y(x, 0) = -h[1 - V(x, 0)] \\ &|\, V(x, y)\,| < U_0 \log\left[1 + (e - 1)\frac{M}{U_0}\right] \end{aligned}$$

The converse can again be established and hence it follows that Problem IV has a unique solution bounded between 0 and U_0, and that this solution can be approximated by a convergent iterative process in which the successive iterates lie alternately above and below the solution.

LITERATURE CITED

COURANT, R. AND D. HILBERT. Methods of mathematical physics. New York: Interscience Publishers, Inc. Vol. **1**: 277.

MANN, W. ROBERT AND F. WOLF. 1951. Heat transfer between solids and gases under nonlinear boundary conditions. Quarterly of Applied Math. **9**: 163–184.

——— AND J. F. BLACKBURN. 1954. A nonlinear steady state temperature problem. Proc. Amer. Math. Soc. **5**(6): 979–986.

ROBERTS, J. H. AND W. ROBERT MANN. 1951. A nonlinear integral equation of Volterra type. Pacific Jour. of Math. **I**: 431–445.

NORTH CAROLINA EARTHQUAKES: 1957

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Introduction and Acknowledgments.—While North Carolina is not generally considered to be very seismic, one or more small shocks occur somewhere in the state almost every year. These shocks, while of little economic importance, are of considerable interest in that they give valuable clues to the geologic structure of the region, and also form an integral part of what may be called the "natural history" of the state. In the past most of these tremors have gone unrecorded except for casual mention in the daily press but, starting with the establishment of a seismological station at the University of North Carolina in Chapel Hill in 1953, a careful record of such occurrences is being kept. It is planned to publish these records in the form of annual summaries, of which this is actually the second. The first such summary, covering all known North Carolina earthquakes through 1956 has already appeared in this journal (MacCarthy 1957).

During 1957 there were three small earthquakes in North Carolina, all in the western portion of the state, which were strong enough to be reported in the press and to register on the seismographs at Chapel Hill, N. C., and at Columbia, S. C. They occurred on May 13, July 2, and November 24. None of the epicenters could be instrumentally located. They caused no real damage, and their maximum intensities apparently did not exceed in any case 5 or at most 5½ on the Modified Mercalli Intensity Scale. (See Appendix).

These three earthquakes form part of an apparent sequence which has proceded from Northeast to Southwest. The phrase *apparent sequence* is used because real sequences of this sort never seem to hold up: short term series are quite common but always seem to break down after a very few earthquakes. The preceding member of this apparent series occurred on September 28, 1955, on the North Carolina—Virginia border, with its epicenter at about 36.6°N., 81.2°W. (MacCarthy 1956-a, 1957; Murphy 1957).

The map, Figure 1, shows the area over which each of these three shocks was felt and also the apparent or "intensity" epicenters (centers of the disturbed areas). These epicenters are marked with small crosses near each of which will be found the date at which the corresponding earthquake took place. Two closed curves are given for each quake: in each case the outer line delimits the "felt area", while the inner line or lines mark the smaller areas over which the corresponding shocks reached or exceeded an intensity of 4 as judged by the available data. As is usual with earthquakes in this part of the country, these isoseismals define crude ellipses which are elongated more or less parallel to the geologic grain of the region.

As has been said above, the apparent temporal sequence from Northeast to Southwest is almost certainly fortuitous. However, the fact that the three (four if the 1955 earthquake is counted) epicenters all fall very close to a line which is parallel to the (local) trend of the Appalachians and to the general grain of the Piedmont probably has some significance. Yet, since there are a fair number of more or less accurately located epicenters in western North Carolina history, it is all too easy to draw lines across the map so as to connect several of these points. While some of the lines so drawn might be of significance, it is quite certain that the majority of them would be purely fortuitous. (MacCarthy 1956-b).

Some details concerning these 1957 earthquakes are given below. Most of the data were collected by the authors through questionnaire post cards and letters sent to postmasters, newspaper editors, law enforcement officers, and certain farmers in the affected areas. Replies were received from well over half of the people so queried. Tennessee data were obtained from Mr. Berlen C. Moneymaker, Chief Geologist of the T.V.A. Readings of the Columbia, S. C., seismograms were furnished by Prof. Charles Mercer of the University of South Carolina. Dr. William A. White helped with the collection of the data. The map, Figure 1, was drawn by Mr. Frank Zablocki.

Descriptions of Individual Earthquakes. *May 13:* Recorded on the seismograph at Chapel Hill at 09:25:32 EST, and on the one at Columbia at 09:25:27½ EST. Felt over an elliptical area covering approximately 5550 square miles. Apparent epicenter at about 35.8° N., 82° W., some seven miles north and slightly east of Marion. The maximum intensity seems to

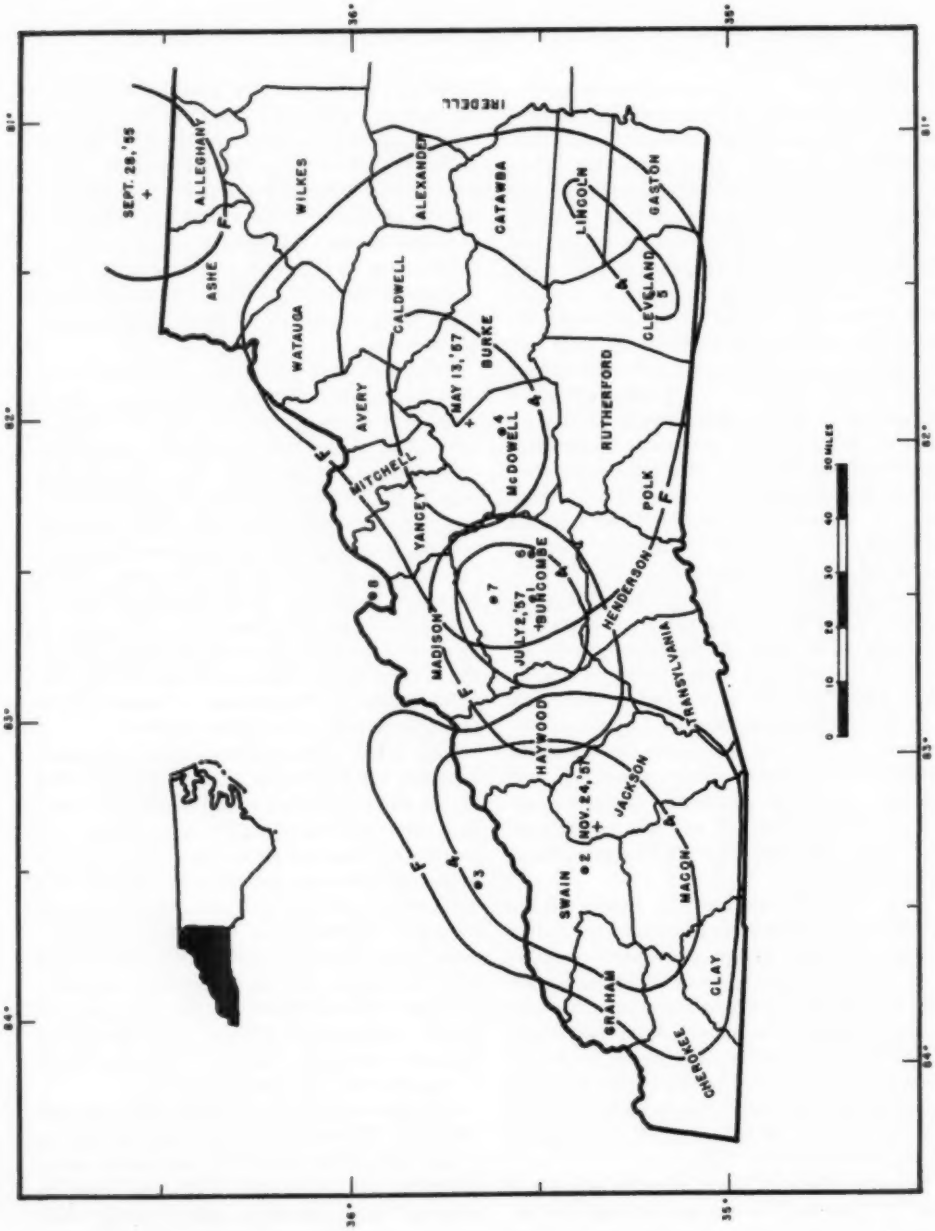

FIG. 1. Map showing locations of earthquakes in North Carolina during 1957. Places mentioned in the text: 1. Asheville; 2. Bryson City; 3. Gatlinburg; 4. Marion; 5. Shelby; 6. Swannanoa; 7. Weaverville; 8. Flag Pond.

TABLE 1

County	No. Localities Where Felt	Estimated Intensities	
		Maximum	Average*
Alexander	3	3	2½
Ashe	1	1–2	1½
Avery	8	3½	3
Buncombe	6	3½	2½
Burke	5	4	3½
Caldwell	11	4	3
Catawba	5	4	3
Cleveland	9	5	3½
Gaston	2	(4)?	2½
Henderson	4	2½	2
Lincoln	3	(4)?	3
Madison	2	3	3
McDowell	8	4½	4
Mitchell	2	4	4
Polk	1	1½–2	1½
Rutherford	5	3	2½
Watauga	6	3	2½
Wilkes	2	3½	3½
Yancey	6	4	3½

* Rounded to the nearest ½ degree of the M.-M. scale.

have been about 5 on the M.-M. intensity scale. The only reported damage was at Shelby where a plaster wall is said to have been cracked. Noises described as "roaring" or "rumbling" were generally reported throughout the area affected by this shock.

Positive reports were received from 89 separate localities in the 19 North Carolina counties listed in Table 1.

Although it was reported as felt within a few miles of both the Tennessee and the Georgia borders, only negative reports were received from these states. It is interesting to note that the three counties from which the greatest number of positive reports were received—Caldwell with 11, Cleveland with 9, and McDowell with 8—form the apices of a triangle which includes Burke with only 5 localities reporting the shock. While this peculiar distribution may be in part due to irregular distribution of actual intensities, it also reflects variations in population distribution, and should not be given too much weight. The intensity figures for Cleveland, Rutherford, and Catawba Counties do seem to indicate a secondary region of relatively high intensities in that area. Hence two separate areas of "high intensity" are marked on the map.

W. A. White (1950) has postulated a major fault paralleling the foot of the Blue Ridge. It seems quite possible that the elongate high intensity area, which extends from eastern Buncombe northeasterly to northwestern Caldwell County, indicates that the disturbance was caused by a slight slippage along White's fault, or along a closely parallel one. If this is true, then the secondary high intensity area which centers in Cleveland County must either be an artifact produced by the use of incomplete data, or be due to a separate shock caused by a slip along another fault in that area. Such "twin earthquakes", as they are sometimes called, are not very common, but *are* known. It is generally supposed that in such a case the secondary shock is initiated by the triggering action of the vibrations from the primary shock setting off a slippage along the second fault which, as it were, is "all cocked and ready to let go." Unfortunately neither the descriptive data nor the records traced by the seismographs can decide the matter in this particular case.

July 2: Recorded on the seismograph at Chapel Hill at 04:33:(42) EST., and on the one at Columbia at 04:33:01. The phases were weak and ill-defined on both seismograms. It was felt over an elliptical area of 1200 square miles, or a little more. The apparent epicenter was near 35.6° N., 82.7° W., about ten miles southwest of Asheville. While it affected a much smaller area and, judging by the amplitudes recorded on the seismograms, was of considerably less magnitude, its maximum intensity in the epicentral area seems to have been at least as great as in the case of the May 13 shock. Some damaged chimneys and cracked plaster were reported from Swannanoa and some cracked plaster noted at Weaverville, both in Buncombe County. The maximum intensity appears to have been about 5½. Roaring or rumbling noises, frequently compared to the sound of thunder, were quite generally reported.

While positive reports were received from only three North Carolina counties—Buncombe, Haywood, and Madison—they represent some 30 individual replies from 17 different communities. In addition to these three counties, it seems very probable that portions of Transylvania and Henderson Counties also felt the shock, although no positive reports were received from them. One report, which can scarcely be authentic, states that the shock was felt lightly at the village of Flag Pond, in Unicoi County, Tennessee. These reports are shown in Table 2. One rather striking

FIG. 1. Map showing locations of earthquakes in North Carolina during 1957. Places mentioned in the text: 1. Asheville; 2. Bryson City; 3. Gatlinburg; 4. Marion; 5. Shelby; 6. Swannanoa; 7. Weaverville; 8. Flag Pond.

thing about this tremor is that while it was reported by relatively few people, the majority of reports received give it a fairly high intensity rating. This was due to the time of occurrence, at about 4:33 a.m., when almost everyone was sound asleep so that, except where the shock was strong enough to awaken people, it went almost unnoticed. Actually, the low intensity portion of the felt area was probably considerably larger than the available data indicate.

Little more can be said concerning this shock except to note that the distribution of intensities—relatively high near the center, but falling off very rapidly with increasing distance—suggests that it must have had a very shallow focus. The small amplitudes on the seismograms indicate that relatively little energy was released and this, taken in connection with the relatively high epicentral intensity, also indicates a rather shallow depth of focus.

As with the May 13 shock, the areas of greatest apparent intensities—Swannanoa and Weaverville—are located eccentrically in respect to the center of the disturbed area. In view of the extremely limited and incomplete data available this seeming peculiarity probably has no significance.

November 24: Recorded at Chapel Hill at 15:07:37½ EST and at Columbia at 15:06:47. Felt over an irregular ellipse enclosing about 3400 square miles. The apparent epicenter was at approximately 35.4° N., 83.8° W., close to Bryson City. The maximum intensity seems to have been about 5 or slightly higher near Gatlinburg Tenn., where a cracked window was reported. Rumbling and roaring noises were generally reported throughout the affected area.

This tremor was reported as felt in 39 different localities in eight North Carolina Counties, and from five localities in three different Tennessee counties, as shown in Table 3. Although felt to within a few miles of the Georgia and South Carolina borders, this tremor does not seem to have been noticed in these states. The only damage reported was in the Gatlinburg, Tenn. (Sevier Co.) area, where a window is said to have been cracked. If the damage was actually caused by this earthquake (which seems a bit doubtful), this would indicate that the region of greatest intensity was located close to the northwestern edge of the affected area, rather than towards its center.

TABLE 2

County	No. Localities Where Felt	Estimated Intensities	
		Maximum	Average*
Buncombe	13	5½–6	4
Haywood	3	4–4½	4
Madison	1	2½	2½
Henderson	0	?	?
Transylvania	0	?	?

* Rounded to the nearest ½ degree of the M.-M. scale.

TABLE 3

County	No. Localities Where Felt	Estimated Intensities	
		Maximum	Average*
North Carolina			
Cherokee	4	4½	4
Clay	4	4	3
Graham	4	4	3
Haywood	8	4	3½
Jackson	8	4½	3½
Macon	4	4	3
Swain	5	4½	3½
Transylvania	1	3	3
Tennessee			
Blount	1	1½	1½
Cocke	3	4(?)	3
Sevier	1	5(?)	(?)

* Rounded to the nearest ½ degree of the M.-M. scale

Although the area over which it was felt is distinctly elliptical, the isoseisms outline a very irregular ellipse, with an eccentric elongation which follows rather closely the crest of the Smokey Mountains.

Despite the fact that it occurred shortly after 3:00 p.m. on a Sunday afternoon this earthquake was not too well reported. The weather was quite stormy over a large part of the affected area and doubtless many people attributed the rumbling and shaking to thunder and hence did not realize that an earthquake was in progress.

APPENDIX

All intensities mentioned in this paper are based on the "Modified Mercalli Intensity Scale of 1931" (Wood & Neumann, 1931). This is the scale now in general use throughout the United States and in many other parts of the world. An abridged version is given below.

MODIFIED MERCALLI INTENSITY SCALE OF 1931

I: Not felt except by a very few under especially favorable circumstances.

II: Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III: Felt quite noticably indoors, especially on upper floors of buildings, but many people do not recognise it as an earthquake. Standing autos may rock slightly. Vibrations like those of passing truck. Duration may be estimated.

IV: During day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sounds. Sensation like heavy truck striking building. Standing autos in general are rocked.

V: Felt by almost everyone, many awakened at night. Some dishes, windows, etc. broken. A few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI: Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of falling plaster and damaged chimneys. Damage slight.

VII: Everybody runs outdoors. Damage slight in buildings of good design and construction, slight to moderate in well-built ordinary structures, considerable in poorly designed or poorly built structures; some chimneys broken. Noticed by people driving autos.

VIII: Damage *slight* in especially designed structures, *considerable* in ordinary substantial buildings, with partial collapse; *great* in poorly built structures. Panel walls thrown out of frames. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving autos disturbed.

IX: Damage *considerable* in especially designed structures; well-designed frame buildings thrown out of plumb. Damage *great* in substantial buildings, with partial collapse. Buildings shifted off foundations; ground cracked conspicuously. Underground pipes broken.

X: Some well-built wooden structures *destroyed*: most masonry and frame structures destroyed, together with their foundations; ground badly cracked. Rails bent. Considerable landslides from river banks and steep slopes. Sand and mud shifted. Water splashed or slopped over banks.

XI: Few, if any, masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII: Damage "total". Waves seen on surface of ground. Lines of sight and lines of level visibly distorted. Objects thrown upward into air.

NOTE: It is usual to rate a given shock as of the highest degree consistent with this scale. No arbitrary scale such as this, based on *effects* alone, can do more than give a rough idea of the energy involved, since effects vary so much with type of ground, type of construction, and other factors difficult to assess.

LITERATURE CITED

MACCARTHY, G. R. 1956a. The southeastern Appalachian earthquake of September 28, 1955. Earthquake Notes **27**(1): 1–2

——— 1956b. A marked alignment of earthquake epicenters in western North Carolina and its tectonic implications. Jour. Elisha Mitchell Sci. Soc. **72**: 274–276

——— 1957. An annotated list of North Carolina earthquakes. Jour. Elisha Mitchell Sci. Soc. **73**: 84–100.

MURPHY, LEONARD M. 1957. United States earthquakes, 1955. U. S. Coast and Geodetic Survey. Washington. 8–9.

WHITE, W. A. 1950. The Blue Ridge front—a fault scarp. Bull. Geol. Soc. Amer. **61**: 1309–1346.

WOOD, HARRY O. AND FRANK NEUMANN. 1931. The modified Mercalli intensity scale of 1931. Bull. Seis. Soc. Amer. **21**(4): 277–283

STUDIES OF THE LIFE HISTORY OF THE CYPRINID FISHES *NOTROPIS GALACTURUS* AND *RUBRICROCEUS*

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Notropis galacturus (Cope) and *Notropis rubricroceus* (Cope), small cyprinid fishes found commonly in the upper Tennessee River system, were described from tributaries of the Holston River, Virginia, by E. D. Cope in 1867 and 1869 respectively.

Most of the specimens used in the present studies were collected in tributaries of the French Broad River near Mars Hill, Madison County, North Carolina. Additional materials were borrowed from the Cornell University Fish Collection. Stream observations and laboratory studies were conducted as described for *N. coccogenis* (Outten, 1957: 68–69).

This account is derived from a thesis submitted to the Graduate School Faculty of Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Grateful appreciation is expressed to Dr. Edward C. Raney, under whose guidance the studies were conducted, and to others who offered suggestions, as Drs. Charles E. Palm and Clifford O. Berg, or assisted with obtaining specimens.

Synonymy

Notropis galacturus (Cope). Whitetail Shiner

See original thesis (Outten, 1956: 31–36) for complete data and references.

Hypsilepis galacturus.—Cope, 1867: 158, 160–161 (original description).

Plargyrus [<*Rutilus*, Rafinesque (=*Leuciscus*, Klein, European); <*Hypsilepis*, Cope] *galacturus.*—Jordan, 1876: 287 (synonymy, descr., range).

Cyprinella galactura.—Jordan and Copeland, 1876: 153 (range).

Luxilus galacturus.—Jordan, 1877: 370, 373, 375 (distribution).

Photogenis galacturus.—Jordan and Brayton, 1878: 18, 20, 32, 64, 78, 84, 92 (distr.).

Hudsonius galacturus.—Jordan, 1880: 292 (descr., range).

Cliola galactura.—Jordan and Gilbert, 1883: 179–180 (descr., range).

Notropis galacturus.—Jordan, 1885: [25] (range).

Erogala galactura.—Jordan, Evermann, and Clark, 1930: 129 (syn. in part, range).

Leuciscus kentuckiensis [Not of Rafinesque].—Günther, 1868: 251–252 (syn. in part, descr., loc.).

Notropis rubricroceus (Cope). Saffron Shiner

See original thesis (1956: 63–66) for complete data and references.

Hybopsis rubricroceus.—Cope, 1869: 231–232, 241, 245, Pl. 24, Fig. 4 (original description).

Alburnops rubricroceus.—Jordan, 1878: 420 (range).

Hydrophlox rubricroceus.—Jordan and Brayton, 1878: 8, 19, 32, 36, 37, 56, 64, 85, 92, 94 (distr.).

Luxilus rubricroceus.—Jordan, 1880: 294–295 (descr., range).

Minnilus rubricroceus.—Jordan and Gilbert, 1883: 189–190 (descr., range).

Notropis rubricroceus.—Jordan, 1885: [26] (range).

DISTRIBUTION. *Range.*—Members of *galacturus* occur in the upper Tennessee River system in Virginia, Tennessee, North Carolina, Georgia, Alabama, and Mississippl (Evermann, 1918: 342); tributaries of the Cumberland River in Tennessee and Kentucky (Kirsch, 1893: 260–267); and the White River system in Arkansas and Missouri (Meek, 1895: 77, 82, 90–92). Specimens of *galacturus* were taken in the Current River near Doniphan, Ripley County, Missouri, on August 13, 1953, by Drs. C. Richard Robins and William S. Woolcott. Collections of this species have been recorded from the St. Francis and the Savannah river systems and were examined by Dr. Robert H. Gibbs, Jr. (Gibbs, 1957: 193). Specimens of *galacturus* were taken in Wolf Creek, tributary of the New River (Kanawha-Ohio system), at Grapefield, Bland County, Virginia, on July 27, 1954, by Dr. Robert D. Ross and in the Linville River (Catawba-Wateree-Santee drainage), Burke County, North Carolina, by Drs. Harry W. Freeman and J. Frank Randall. The presence of introduced species in the latter area has been noted by Dr.

Joseph R. Bailey. Members of *rubricroceus* are found in the upper Tennessee River system in Virginia, Tennessee, and North Carolina.

Habitat.—Individuals and schools were observed in the middle to upper levels of small and medium-sized mountain streams having fairly clear water and moderate current. In periods of little precipitation and low water level, the volume of flow was measured as 6.4 cubic feet per second in Bull Creek and 10.4 cubic feet per second in Little Ivy Creek using the method of Robins and Crawford (1954: 367). More abundant near riffles, members of *galacturus* were often in the deeper pools, especially alongside a steep rock bank or a large boulder with a submerged overhanging ledge which could be used as shelter when disturbed, and *rubricroceus* in somewhat shallow pools. Rocks, bedrock, and rubble were frequently present in near-by riffles. Other than a slight growth of algae, generally there was little or no vegetation on the submerged rocks. In a few areas, *Podostemum ceratophyllum* was attached to the surface of rocks in shallow, somewhat rapid water. Gravel and coarse sandy bottoms seemed to be preferred. At times, less mature representatives of *galacturus* were found in considerable numbers in small tributaries.

Associates.—Specimens of *galacturus* and *rubricroceus* were often taken in the same stream. Other species seen or taken along with the preceding included: *Moxostoma duquesnei* (LeSueur), *M. erythrurum* (Rafinesque), *Hypentelium nigricans* (LeSueur), *Hybopsis* sp., *H. micropogon* (Cope), *H. a. amblops* (Rafinesque), *Rhinichthys atratulus obtusus* Agassiz, *Notropis leuciodus* (Cope), *N. coccogenis* (Cope), *N. spilopterus* (Cope), *N. spectrunculus* (Cope), *Campostoma a. anomalum* (Rafinesque), *Micropterus d. dolomieui* Lacépède, *M. salmoides* (Lacépède), *Ambloplites r. rupestris* (Rafinesque), *Percina evides* (Jordan and Copeland), *Etheostoma swannanoa* Jordan and Evermann, *E. flabellare* Rafinesque, and *Cottus bairdi* subsp. Additional species taken with *galacturus* were: *Catostomus c. commersoni* (Lacépède), *Rhinichthys cataractae* (Valenciennes), and *Lepomis m. macrochirus* Rafinesque; accompanying *rubricroceus: Salmo gairdneri* Richardson (seen) and *Phenacobius uranops* Cope.

Predators.—*Natrix s. sipedon* Linnaeus took specimens from spawning groups. Individuals of *M. d. dolomieui* and *M. salmoides* moved in such a manner as to greatly disturb and immediately disperse groups of smaller fish. *Megaceryle a. alcyon* (Linnaeus) captured fishes from streams where these species were active.

GENERAL BEHAVIOR.—Individuals and small to moderate-sized schools swam slowly against the current in their endeavors to locate food and to maintain a fairly constant position. Short excursions were often made to adjoining pools. Members seemed to be active at all hours of daylight throughout the year.

REPRODUCTION. *Age and size at maturity.*—Some individuals show considerable development during their second summer and generally all attain maturity by the time they are two years old. Among the age-group II specimens taken in the Little Ivy Creek system near Mars Hill, N. C., for *galacturus* the standard length of the males ranged from 46 to 95 mm. (mean 70.7), the females from 41 to 78 mm. (mean 61.8); for *rubricroceus* the males 44 to 59 mm. (mean 51.8), females 42 to 61 mm. (mean 51.5).

Sexual dimorphism.—The average standard length of mature males of *galacturus* is slightly greater than that of the females, about equal or slightly more in *rubricroceus*, as shown above. In mature members of both species, the male is generally more slender with the lateral body wall fairly straight rather than rounded or somewhat swollen, as is often true for females in the spring. In the males of each of the species, the pelvic fins are of noticeably greater length, the pectorals just slightly longer.

N. galacturus.—During the spawning season, large, mature males have the lateral and ventral parts of the body milky white, with the characteristic white areas at the base of the caudal fin more pronounced. The pelvic and anal fins are whitish with a distinctly white border along the outer part, more pronounced on the latter. The pectoral, dorsal, and caudal fins have a slight reddish tinge distally and a faint suggestion of white along the posterior edge, more prominent on the tips of the pectorals and caudal. Well-developed tubercles cover the tip of the elongated snout and lateral margins of the upper jaw, are arranged in two staggered rows between the nostrils and eyes, and scattered, though close together and numerous, over the top of the head back to the occiput. Two irregular rows of weakly developed tubercles line the margins of the lower jaw. Rows of small, but well developed, pearl organs extend along the dorsal surface of the pectoral fin rays. Tubercles are poorly developed on

other fin surfaces. The very small, sparsely distributed prominences on the scales are most abundant dorsally. Females are grayish to slightly greenish-tan dorsally, light silvery laterally and on the ventral surface, and without tubercles, prolonged snout, encrusted scales, or red on the fins.

N. rubricroceus.—At spawning time, males have the snout slightly prolonged and somewhat bluntly pointed with reduced tubercle development around the tip. It is delimited by a pronounced transverse ridge in front of the nostrils. Over the nest, the heart-shaped area on the top of the head from the back of the eyes to the occiput, middorsal line which extends from the nape to the dorsal fin then continues posteriorly to the base of the caudal fin as a series of dots, longitudinal stripe midway the side of the body from the operculum to the caudal peduncle, and fins are golden yellow. After being in ten per cent formalin for one to two hours, the red is still present on the snout and dorsal part of the body but is less intense ventrally. Much of the yellow is retained in the fins with the top of the head, middorsal stripe, and lateral stripes appearing olivaceous. Most numerous on the snout and the top of the head with slight development on the lower jaws and operculum, many very small, scattered tubercles cover the head and body of mature males taken before and during the spawning season. The caudally directed pearl organs on the body and back of the head are most abundant near the posterior margins of the scales, often in a diamond-shaped arrangement. On the nape, tubercles are also present near the center of scales. The laterally spread pectoral fins are supported by semi-rigid, stout, tubercle-bearing rays with the sturdier first ray considerably enlarged by the addition of a thick, rigid layer anteriorly. On the dorsal surface of the first three to four pectoral rays are medially directed tubercles with recurved spines which suggest that the pectoral fin of the male may be used to grasp the female during spawning. Modification of the pectoral fins of breeding males of *Notropis p. procne* (Cope) has been described (Raney, 1947a: 104). The ventral surface of the pectoral fin and the entire pelvic fin lack well-developed tubercles. Those on the median fins are small, more numerous near the base and toward the leading edges. Males taken in the early fall have two to three rows of slightly enlarged tubercles extending anteriorly from the area in front of each eye to the tip of the snout and about one to two rows of similar, though sometimes poorly developed, ones on each side of the lower jaw.

Females are much less brilliant. The body is olivaceous dorsally with a small red area at the tip of the snout and slightly suffused with red anteriorly and laterally below the lateral stripe. The pectoral fin contains soft, flexible rays and is held close to the body. Mature females have two to three irregular rows of slightly enlarged pearl organs extending from the area in front of each eye and below the nostril to the tip of the snout, resembling those similarly located on the male during the fall. There is a single, short row of pearl organs in the area between the eye and the nostril. A few additional large prominences are scattered about on the anterior part of the snout and in the space which separates the nostrils. Generally a single row extends along the edge of the mandible. Many very small tubercles are scattered over the top and sides of the head and on the scales. The scales of females are only slightly encrusted.

Fecundity.—Studies were made of the ovaries and eggs of forty preserved specimens of the larger swollen females of *galacturus* ranging from 57 to 86 mm. in standard length, one to four years in age, and collected from March 29 to July 3 and of forty-two similar specimens of *rubricroceus* 40 to 67 mm. in standard length, of the same age groups, and taken from April 25 to July 14. The procedure followed was the same and the general form of the gonads and eggs similar to those observed in the study of *coccogenis* (1957: 71–72). Preserved in formalin, mature eggs with the chorion were about 1.6 mm. in diameter. In the spring, the ovaries of large females of *galacturus* contained from 404 to 1815 mature eggs, *rubricroceus* 445 to 1174.

Spawning. N. galacturus.—Egg-laying activities were observed twice at the under surface of the overhanging edge of a paper fertilizer sack supported by a large boulder about 2½ feet in diameter near the middle of the stream, which was ten to twelve inches deep in the area. About one foot from the upstream side of the boulder was a smaller rock that helped to support the sack and aided in enclosing the space. A strong current of water flowed through the narrow passageway between the boulder and the rock. To the side and slightly downstream from the nest was a pool about three feet wide by four feet long and twenty inches deep. Spawning was noted three times at

the under surface of a severed, floating, partly submerged limb of a black locust tree which projected out from the bank almost opposite and slightly upstream from the large boulder. The tree limb was about three inches in diameter and seven feet long. In the immediate area the water was about six to eight inches deep and the bottom fairly level. Near the center and at the opposite side of the stream, there were pools ten to fifteen feet away, to and from which individuals and small groups swam frequently.

The larger, more brightly colored males were observed holding territories at nests. The male held singly a position commanding access to a favorable spawning location and drove away other fish, especially males of the same species. The position taken was of a roving nature; he was constantly moving about the area around the nest, first to one side and then to the other. There were frequent inspections of the nest with short excursions to the surrounding vicinity, a near-by pool, and other possible spawning sites. When another fish sought to enter the area, he moved to a position between the intruder and the nest. Sometimes in the efforts to resist the challenger there resulted a circular, chasing movement with the two going around in a path of small circumference, the head of the guardian approaching close to the tail of the intruder. This behavior was observed to continue for many revolutions and some little duration of time. Males of *Notropis p. procne* guarding a territory over the spawning ground have been observed to chase in a circular path other males of the same species that sought to enter the area (Raney, 1947a: 106). The territory-holding male often escorted the intruder away from the area by swimming alongside or slightly behind the individual until he was a considerable distance from the nest.

At the time of spawning, there were in the vicinity of the nest several moderate-sized, less colorful females, one large brightly colored male, and a smaller male that, although seen now and then, was not observed to take part in the activities. The larger male was constantly moving about in order to prevent the entry of other fish into the nest area. The females were headed toward the nest and against the current in the narrow passageway leading from the pool. In spawning, the large male and a smaller mature female came up under the overhanging structure at the same time. As simultaneously they turned over on their sides, the ventral body region was pressed up to the lower surface of the projecting cover and toward the accompanying individual. They paused in the area briefly and then swam away, generally in opposite directions. The behavior was repeated several times in succession. Spawning was observed to continue for as much as seven minutes without interruption. After a period of egg laying, the female retired to the pool and was not seen to take any part in the care of the eggs or nest. The male remained in the area guarding the nest. Spawning was observed at times from May 25 through June 28 near the middle of the day, from 11:35 to 3:45, with the air temperature 84° to 89°, the water 75° to 82°F., and the sky fairly clear.

During the period from May 28 through July 17, sixteen nests where spawning had been observed, or similar locations, were found with eggs. Two groups of eggs were adhering to the under surface of the paper fertilizer sack, seven groups were attached to the side of the large boulder or nearby objects, and seven groups were on the lower surface and extending into crevices under the bark of floating tree limbs. The tendency of the *Cyprinella* to deposit eggs on submerged objects has been noted by Hankinson (1930: 74), Greeley 1935: 94), and Stone (1941: 289).

Some of the egg clusters were about four inches long by one inch wide and three inches below the surface of the water. The eggs were somewhat adhesive on the outer surface and adhered slightly forming small clusters of a half dozen or less. The number of eggs in the larger groups ranged from 127 to 382 with an average of 249. Comparison of the small to moderate numbers of eggs found at nests with the greater abundance of ripe eggs in mature ovaries suggests that in order to deposit all of the fully developed eggs spawning may occur several times a season.

Study of eggs in the laboratory revealed that many contained living embryos. Some of the eggs collected on June 28 had embryos which measured 3.5 mm. in total length. Eggs obtained on July 14 contained living embryos in an advanced state of development. After hatching, the young larvae were about 5.2 mm. in total length. By the next day, additional larvae had hatched, some of which measured as much as 5.5 mm. in total length.

N. rubricroceus.—Aggregations of *rubricroceus* associated for spawning were observed on forty different occasions from May 1950 through June 11, 1958. Nests of *Hybopsis micropogon* were

utilized by members of *rubricroceus* for spawning. Large adult males of *H. micropogon* were seen adding to and rearranging materials of the nests as well as holding territory and spawning over the area. The tendency of some cyprinids to use the nests of other fishes, particularly those of *H. micropogon*, has been reported by others as mentioned in the study of *coccogenis*. Gravel from ¼ to 2¼ inches in diameter was arranged in low heaps about 22 to 24 inches long by 18 to 20 inches wide, rising 5 to 6 inches above the bottom of the stream, with the water 5 to 12 inches deep over the top of the nest. Often there was a slight depression about 2½ inches deep near the central to upstream part of the nest surface. Generally, nests were located downstream from riffles or where the current was moderately rapid and near one or more pools approximately 3 to 5 feet long by 2 to 3 feet wide and 15 to 20 inches deep.

Fairly large groups of thirty to forty or more brightly colored males held territories as they swam against the current down low over the central to upstream part of the nest. Less brightly colored individuals occupied posterior positions over the downstream and peripheral parts of the area. Occasionally the entire group seemed to extend from the center of the nest backward. At times the aggregation was spread out covering an area slightly larger than the nest. The group was continually in motion to counteract the effects of the current and to drive away intruders or rivals. In some instances two to three males moved together, rushing toward an intruder with such vigor that the disturbing individual usually turned and swam away, followed for a short distance by the defenders. At times a bright red male seemed to challenge another male of less brilliant coloration concerning a position over the nest with the two swimming off to the side for a short distance.

Spawning groups, consisting largely of bright red males (as many as forty to sixty), occupied positions similar to those held during pre-spawning activities. The small number of females present were in a slightly posterior position and along the downstream edge of the nest. Although the aggregation was often spread out, at times it formed a rather compact, cylindrical cluster. The greatest density of the group seemed to be over a depression near the central to upstream part of the nest.

Preparatory to spawning, the females came to the downstream edge of the area, where they paused momentarily. As a female moved forward to the central part of the nest, going a short distance at a time in some instances, she was joined by one or more males. The female, together with her escort, settled down over the depression in the central to upstream part of the nest, where, with considerable vibration of their bodies and agitation of the water, spawning took place. The activity induced other males to rush to the area, crowding around the group and forming a jostling, wriggling cluster. After a brief period, the performance terminated and the group dispersed. The males again took positions over the nest. It was not easy to follow the female among the moving fish, but it seemed that, temporarily at least, she returned to the adjoining pool. A time or so when approaching the nest as if preparatory to spawning, the female swam off to the side for a short distance followed by two or three males, then returned to the nest and spawned in the usual manner.

The territory holding by the males, manner of the females approaching the nest from the rear, and spawning cluster of *rubricroceus* resemble the spawning behavior of *Chrosomus oreas* which has been described by Raney (1947b: 127).

Groups were observed guarding the nest area at times from May 12 through July 21, as early as 5:23 A.M. and until 7:10 P.M., at temperatures of air 54° to 93°, water 61° to 86°F., spawning from May 25 through July 21, from 5:30 A.M. until 6:20 P.M., at temperatures of air 67° to 90°, water 66° to 86°F. Individuals were more active over the nest when the sun was shining on the area, but were seen to continue to be present when the sky was hazy and overcast with clouds. One group remained over the nest during a light rain. Spawning activity was more frequently observed from the middle of the morning to the early part of the afternoon, i.e., from ca. 9:30 A.M. to 2:30 P.M., usually when the sky was clear.

Following spawning activity, small, immature individuals of *H. micropogon* often managed to crowd into the central region of the nest where each moved his snout among the small stones as if searching for eggs.

Members of the spawning group were briskly vigilant in trying to guard the nest and drive away other fishes that attempted to obtain eggs. Individuals and groups of the assembled males would dash toward the intruders in an unquestionably pugnacious manner. During the early

part of the spawning activity, the territory-holding members were able to keep the area relatively free from outsiders. After spawning had continued for a while, the aggregation of *rubricroceus* remaining over the nest became considerably diminished. At the same time, the number of would-be poachers increased. Later, the much depleted spawning residuum was unable to keep off the intruders with resulting interference of the egg-laying activities. As the group dwindled and spawning became sporadic, few to not any bright red males remained. However, a group of less brightly colored, slightly reddish individuals continued to hold positions over nests for as long as two hours.

AGE AND GROWTH.—Standard length, age, sex, and maturity were ascertained for each specimen in a manner similar to that used in the study of *coccogenis* (1957: 73–74). Age was determined by counting the annuli of the scales, the validity of which has been demonstrated for other species as indicated in the earlier study. The circuli of the scales are concentric, approaching circular in outline, and fairly regular in form. The year marks are readily seen in the original squamation of the younger age groups. On the scales of older specimens, the winter marks near the edge are closer together and less regular.

The annulus is shown by "cutting over" as the more recently added circuli cut across the outer ones of the past season in the area along the lateral to posterolateral margins. The relative approximation of the ridges, widely spaced during the late spring and early summer period of more rapid growth and more compact in the fall and winter period of less growth, generally rather limited to very little, is also indicative of the annulus. In the vicinity of Mars Hill, N. C., most individuals of *galacturus* seemed to form the annulus about, or shortly after, the middle of April, *rubricroceus* during the latter part of April. Beyond the initial growth, often considerable, of early spawned young of the year, greatest increase in size was made by age-group I with further increments in reduced amounts the following years.

N. galacturus.—The scales are broadly oval (Cockerell and Callaway, 1909: 190, 194, Pl. IV, Fig. 25) with the curvature of the anterior margin very slight, the sides considerable, and the posterior edge intermediate between deeply rounded and bluntly pointed. The scales are considerably wider than deep; at times the width is one and one-half times the depth. The basally located focus is less than one-fourth the depth from the anterior margin. The scales of moderately large specimens have in the apical field approximately sixteen weakly outlined radii, about six of which are primary. Young of the year from Ivy Creek and tributaries averaged 33.8 mm. in standard length by the period between September 15 and October 18. One-year-old specimens collected between October 10 and 18 showed an average increase in standard length of 21.3 mm. (65.1 per cent) over that of young of the year taken during the same period, age-group II 18 mm. (33.3 per cent) over individuals that were one year old, group-III specimens 8.5 mm. (11.8 per cent) over the same class of the preceding year (Table I). The largest individual was a two-year-old male 101 mm. in standard length. The maximum size for a female, 94 mm., was represented by a three-year-old specimen. Of the 3115 specimens studied, 503 (16.1 per cent) were young of the year, 2159 (69.3 per cent) one year old, 419 (13.5 per cent) of group II, 33 (1.1 per cent) three years old, and one (0.03 per cent) four years old. The oldest specimen was a four-year-old female 80 mm. in standard length.

N. rubricroceus.—The scales have the form of a broadly rounded shield. The anterior margin is only moderately curved, giving the appearance of a straight line bulged slightly in the center to form a convex surface. There are fairly distinct rounded corners at the anterolateral margins. The gently tapered sides lead posteriorly to a bluntly rounded point near the center of the apical margin. The scales are slightly wider than deep, one of a 58 mm., two-year-old female was 2.3 mm. wide by 2 mm. deep. The focus is located in the basal part of the scale, about one-fourth of the depth from the anterior margin. There are about fourteen apical radii, including six to seven primary ones. One-year-old specimens from Ivy Creek and tributaries showed an increase in mean standard length of 46.2 per cent during the period from February 27 to July 14. The average standard length of two-year-old individuals was 43.4 per cent greater than that of group-I members taken during the same period, group-III specimens 17.2 per cent greater than that of the next younger group. The largest individual was a four-year-old female 67 mm. in standard length, the largest males 59 mm. in standard length, two and three years old (Table II). The 2215 specimens studied were distributed among the differ-

TABLE 1

Standard-length distributions (in mm.) by age and sex of 3048 specimens of Notropis galacturus *from the Tennessee and Cumberland river systems in N. C., Va., and Tenn.*

Range, mean, and number of specimens (in parentheses) are given.

Locality	Date	Age Group								
		0		I		II		III		IV
		M	F	M	F	M	F	M	F	F
French Broad R., Sevier Co., Tenn.	Aug. 31	28–36	31–33	51–71	50–56					
		31.4	32.0	59.6	53.0					
		(11)	(2)	(7)	(2)					
Spring Creek, Madison Co., N. C.	Sept. 12	23–52	24–36	56	59					
		32.5	29.2							
		(7)	(9)							
Ivy Creek and tribs., Madison and Buncombe counties, N. C.	Sept. 15–Oct. 18	20–50	19–54	38–76	42–76	65–93	52–73	64	66–84	
		34.1	33.5	54.4	53.5	74.7	62.9		74.8	
		(225)	(225)	(95)	(132)	(28)	(44)		(5)	
Paint Fork, Madison Co., N. C.	Feb. 27			30–45	28–31	46–66	41–58	68–71	63	
				34.2	30.4	56.2	51.1	69.5		
				(8)	(8)	(15)	(17)	(2)		
French Broad R. tribs., Buncombe Co., N. C.	March 29			38–49	36–44	71–93	63–79		83–86	
				41.3	39.6	81.9	69.9		84.7	
				(3)	(3)	(7)	(9)		(3)	
N. Fork Holston R., Smyth Co., Va.	April 1			43–50	44–52	52	46–67	60	71	
				48.9	48.1		54.6			
				(7)	(10)		(4)			
Ivy Creek tribs., Madison Co., N. C.	April 3			27–53	25–51	49–67	45–65	71		
				39.2	36.8	57.4	53.1			
				(139)	(114)	(21)	(48)			
French Broad R. tribs., Madison Co., N. C.	April 10–24			23–55	22–56	56–64	46–57		68	
				32.9	32.2	59.5	50.0			
				(152)	(141)	(4)	(6)			
Little Ivy Creek, Madison Co., N. C.	April 25–May 9			28–49	26–64	67–88	55–78	98	79	80
				36.5	38.0	76.0	67.2			
				(14)	(14)	(6)	(19)			
Ivy Creek tribs., Madison Co., N. C.	May 22–31			30–62	25–63	57–85	56–72	95	73–82	
				41.5	43.6	71.5	60.2		77.5	
				(27)	(28)	(24)	(19)		(2)	
Reems Creek, Buncombe Co., N. C.	May 28			29–69	29–60	65–101	61–84			
				50.8	45.9	81.7	69.7			
				(4)	(17)	(11)	(7)			
Ivy Creek and tribs., Madison and Buncombe counties, N. C.	June 13–26			22–62	24–61	60–95	37–71		71–94	
				37.0	36.3	73.4	60.8		80.0	
				(495)	(586)	(40)	(45)		(3)	
Bull Creek and backwater pool, Madison Co., N. C.	July 3			35–69	40–64	64–77	59–72			
				55.1	51.4	73.9	66.5			
				(20)	(16)	(7)	(9)			
Cumberland R. tribs., Cheatham, Robertson, and Cannon cos., Tenn.	July 28–30			37–75	38–61	69–78	70–79	100	73–90	
				52.4	48.4	73.5	73.0		84.2	
				(32)	(63)	(2)	(5)		(5)	

ent age groups in the following manner: 520 young of the year (23.5 per cent), 1007 age-group I (45.5 per cent), 539 group II (24.3 per cent), 135 group III (6.1 per cent), 12 group IV (0.5 per cent), and 2 group V (0.1 per cent). The oldest individuals were two five-year-old females of 60 and 64 mm. in standard length.

FOOD AND FEEDING.—Larger specimens were selected for the study of food habits. The procedure followed was like that used for *coccogenis*

(1957: 77–79). The general form of the digestive tract resembles that of *coccogenis* with slight variations. The short bile duct extends from the right lobe of the liver to join the adjacent stomach area at a point about 2.5 mm. posterior to the transverse septum in specimens of *galacturus*, about one millimeter beyond the cardiac valve in *rubricroceus*.

N. galacturus. Materials taken as food.—Mayfly nymphs, found in the stomach contents of speci-

TABLE II

Standard-length distributions (in mm.) by age and sex of 2215 specimens of Notropis rubricroceus *from the upper Tennessee River system in N. C., Va., and Tenn.*

Range, mean, and number of specimens (in parentheses) are given.

Locality	Date	Age Group									
		0		I		II		III		IV	V
		M	F	M	F	M	F	M	F	F	F
Ivy Creek tribs., Madison Co., N. C.	July 1–14	20–23 21.5 (4)	19–21 19.7 (3)	40–54 48.3 (72)	46–51 48.3 (7)	49–54 51.4 (38)	49–55 52.2 (19)		56–63 59.5 (2)		
Indian Creek, Unicoi Co., Tenn.	Aug. 30		24–30 27.2 (5)	47–50 49.0 (5)	48–50 48.8 (4)		56				
French Broad R. tribs., Madison and Avery counties, N. C.	Sept. 15–27	20–44 28.7 (130)	19–40 30.2 (158)	33–52 47.0 (26)	35–51 45.0 (29)	47–55 50.3 (54)	42–55 50.2 (100)	58	51–61 56.3 (39)		
French Broad R. tribs., Madison, Buncombe, and Yancey counties, N. C.	Oct. 3–18	20–40 28.3 (105)	20–40 28.1 (107)	36–56 44.2 (34)	34–50 43.0 (44)	48–56 50.9 (9)	47–60 51.7 (18)		55–58 56.5 (2)		
Upper Tennessee R. syst., Washington Co., Va., and Yancey Co., N. C.	Nov. 2–7	22–32 27.0 (5)	26–33 29.0 (3)	38–52 44.3 (3)	36–44 40.0 (2)						
Ivy Creek tribs., Madison Co., N. C.	Feb. 27–March 24			33–34 33.3 (3)		44–51 47.5 (4)	42–49 47.3 (10)		55–60 56.7 (3)		
Holston R. and tribs., Smyth Co., Va.	April 1			27–41 33.6 (20)	27–36 31.6 (17)	39–49 45.3 (28)	36–50 44.4 (23)	49–56 53.3 (15)	49–55 51.8 (23)	52–57 54.4 (7)	60–64 62.0 (2)
French Broad R., tribs., Madison, Henderson, and Buncombe counties, N. C.	April 3–8			35	31–40 35.8 (5)	43–51 47.9 (7)	42–54 47.0 (8)		59		
French Broad R. tribs., Madison Co., N. C., and Unicoi Co., Tenn.	April 25–30			22–48 32.0 (65)	23–43 31.0 (79)	48–52 50.0 (2)	40–53 47.7 (22)	56	54–61 57.2 (7)	61	
Little Ivy Creek, Madison Co., N. C.	May 2–9			29–42 35.9 (46)	27–44 34.9 (59)	50	46–58 51.8 (8)	56 (2)	55–62 58.3 (10)	63–67 65.0 (2)	
Ivy Creek tribs., Madison Co., N. C.	May 25–31			28–49 38.1 (80)	25–47 36.3 (83)	48–59 53.3 (66)	49–61 54.0 (54)	59	54–64 59.1 (11)		
French Broad R. tribs., Madison and Buncombe counties, N. C.	June 2–7			31–51 41.0 (9)	31–34 32.7 (3)	50–58 53.1 (7)		55–57 56.5 (4)	60		
Holston R. tribs., Smyth Co., Va., and Johnson Co., Tenn.	June 4–9			27–40 32.9 (25)	29–39 34.0 (15)	39–57 49.4 (24)	38–61 46.6 (25)		53–61 56.8 (10)	56–63 59.5 (2)	
Ivy Creek and tribs., Madison and Buncombe counties, N. C.	June 13–26			26–48 38.6 (124)	26–48 37.1 (147)	49	48–56 50.6 (9)	54	57–65 61.0 (2)		

mens from each of the seasons studied, most abundant in the food of the summer season, and comprising the greatest volume of the food items, included *Ephemera* in the spring, several *Isonychia* in the summer, and many *Heptagenia* in the summer and fall diets (Table III). Diptera taken in the spring consisted largely of terrestrial adults and included one snipe fly, *Rhagio*, with many midge larvae and adults, as *Chironomus*, in the summer and fall food. Aphids, adults and nymphs, were found in the stomach contents for each of the three seasons studied. Single food

TABLE III

Food of 35 specimens of Notropis galacturus *collected from Feb. 27 to Oct. 18*

Of 40 stomachs examined, 35 had food. Specimens were 64 to 93 mm. in standard length, one to four years old. Under each season the left column represents the percentage of stomachs with food, the right the percentage content of food by volume.

	Spring Feb. 27–May 26		Summer July 3–28		Fall Sept. 20–Oct. 18		Total for three seasons				
							Stomachs with food		Vol. %	No. of organisms	
Stomachs, examined	15		10		15						
with food	13		10		12		No.	%		Total	Av. per stomach
Food item											
Aquatic Organisms	42.6	17.2	100.0	65.6	75.0	46.2	25	71.4	43.0	200	8.0
Terrestrial Organisms	84.6	73.7	70.0	34.0	83.3	52.6	28	80.0	53.4	165	5.9
Animals	100.0	90.0	100.0	94.6	100.0	78.0	35	100.0	87.5	301	8.6
Vegetation	30.8	0.9	20.0	5.0	41.7	17.9	11	31.4	7.9	17	1.5
Miscellany	30.8	9.1	30.0	0.4	25.0	1.2	10	28.6	3.8	12	1.2
Insecta	69.2	56.4	100.0	86.6	91.7	67.0	30	85.7	70.0	221	7.4
Ephemerida	15.4	5.1	100.0	47.5	33.3	6.3	16	45.7	19.6	74	4.6
Diptera	30.8	3.9	80.0	17.6	58.3	17.5	19	54.3	13.0	78	4.1
Hemiptera	30.8	5.3	30.0	9.2	16.7	5.4	9	25.7	6.6	34	3.8
Trichoptera	7.7	0.7	20.0	1.7	50.0	16.0	9	25.7	6.1	14	1.6
Coleoptera	15.4	13.5	30.0	6.0	8.3	0.6	6	17.1	15.3	12	2.0
Lepidoptera	23.8	21.1			8.3	0.6	4	11.4	7.2	4	1.0
Hymenoptera			10.0	4.5	25.0	10.5	4	11.4	5.0	6	1.5
Odonata	15.4	6.8					2	5.7	2.3	2	1.0
Plecoptera					8.3	0.5	1	2.9	0.2	1	1.0
Dermaptera					8.3	0.8	1	2.9	0.3	1	1.0
Insect eggs	15.4	3.5					2	5.7	1.2	(2 lots)	
Insect remains			20.0	0.1	25.0	8.8	5	14.3	3.0	(5 lots)	
Arachnoidea					25.0	5.6	3	8.6	1.9	3	1.0
Oligochaeta	30.8	30.0	20.0	6.0	8.3	8.3	7	20.0	14.8	7	1.0
Nematoda	7.7	0.1					1	2.9	0.03	1	1.0
Fish			10.0	2.0			1	2.9	0.7	1	1.0
Algae					8.3	2.5	1	2.9	0.8	(1 lot)	
Vascular plants	30.8	0.9	20.0	5.0	33.3	15.4	10	28.6	7.1	(16 lots)	
Misc. residues	15.4	6.9			8.3	0.8	3	8.6	2.6	(3 lots)	
Sand			30.0	0.4	16.7	0.3	5	14.3	10.0	(5 lots)	

items of the water strider, *Gerris*, and the giant wheel bug, *Arilus*, were in separate stomachs of specimens from the spring collections. Among the caddis larvae, *Hydropsyche* were abundant in the stomach contents of summer and fall individuals and *Trentonius* was among the food of a specimen in the fall. Adult beetles, mostly terrestrial, were in the food of individuals collected during all three of the seasons and most numerous during the summer. A few terrestrial larvae and pupae of Lepidoptera were in the food of some of the specimens collected in the spring and in the fall. Dragonfly naiads were in the food of spring-collected specimens. A stonefly nymph and an earwig were in the food of separate individuals collected in the fall. Two lots of eggs were among the food of specimens taken in Little Ivy Creek, May 25–26, 1950. The thirteen larger eggs were about 1.7 mm. by 0.8 mm. and had at one end a rounded caplike structure resembling that found on the eggs of some stoneflies. There were about forty smaller, smooth-surfaced, ellipitic bodies, about 0.3 mm. by 0.2 mm., resembling the eggs of some Ephemeridae. *Lumbricus* remains were found individually among the stomach contents of specimens, four collected in the spring, two in the summer, and one in the fall. Two water mites (Hydracarina), a spider (Aranae), a small roundworm, and some algae were found in the food of different individuals from the fall collections. A fish prolarva was in the stomach of a specimen taken in the summer. Parts of higher plants, such as leaf fragments, small seeds, or tiny bits of bark were among the nutritional intake of some of the specimens from each of the three seasons. The small amounts of sand found were probably taken along with food or through curiosity.

Feeding habits.—Individuals, alone and in small schools, were frequently observed feeding on materials that drifted along in the current. The inclusion in the diet of both aquatic and terrestrial forms in similar, though varying, amounts seems to point out that items are taken largely according to availability. The variety of foods found suggests that a wide range of materials may be utilized.

Factors influencing food eaten.—The protrusile, terminal mouth is suited for taking food in the stream or near the surface, as described for another species by Evans (1950: 11). The sharp-pointed, raptorial pharyngeal teeth with serrulate to dentate grinding surfaces and the short simple alimentary canal may be associated with the use of a considerable portion of animal materials in the food.

N. rubricroceus.—The slightly longer intestine extends forward to a position alongside the most anterior part of the stomach area and just posterior to the transverse septum.

Materials taken as food.—Mayfly nymphs, abundant in the stomach contents of most of the specimens and first in frequency and percentage of stomachs occupied, volume content percentage, and total number of organisms, included *Isonychia* and members of the family Heptageniidae, as *Iron* (Table IV). Second only to the preceding order and surpassing that in percentage of stomachs of spring members in which it was present, Diptera was represented by midge larvae, pupae, and adults in specimens from each of the three seasons with larvae of *Chironomus* abundant during the spring and summer and those of *Blepharocera* present among food items of members taken in the summer. Caddis larvae, found in the stomach contents of individuals from each of the three seasons with the greatest number and volume in the summer diet, included many *Hydropsyche*. Beetles, including an aquatic and several terrestrial adults as well as a larva, were more abundant in the summer and fall food. Hemiptera, present in all three seasons, were most numerous in the fall with many aphids, young and adult, present. A few stonefly nymphs, *Isoperla* and *Allocapnia*, were found in the food of specimens collected in the spring. The stomach contents of members taken in the summer had a considerably greater number of immature Plecoptera, including some *Peltoperla*. Terrestrial Lepidoptera, larvae and pupae, were found in the food of specimens from the spring and summer seasons. Hymenoptera, mostly terrestrial adults, included several ants and one small wasp. Parts of a larva of *Corydalus cornutus* were found in the stomach of an individual collected in the spring. An insect egg, yellow in color, slightly roughened on the external surface, and measuring 0.5 mm. by 0.3 mm., was among the food of a specimen taken in the summer. One spider and parts of a harvestman (Phalangida) were in the stomach of a member collected in the spring. Small spiders were found singly among the food items of specimens, one from the summer and three from the fall. A millipede and part of a member of *Lumbricus terrestris* were found in the stomach contents of different individuals taken in the spring. Algal material, present in small amounts in food of specimens from each of the

three seasons, included *Draparnaldia* in the stomach contents of a member taken in the spring and *Lyngbya* among the food items of specimens obtained during the summer. Higher plants were represented by small seeds and bits of cellulose. Many diatoms, including *Cymbella*, *Diatoma*, *Navicula*, and *Synedra*, were in the remaining yellowish-brown mass of the miscellaneous residues. Sand was probably taken accidentally and as described for *galacturus*.

Feeding habits.—Food-getting activities are performed singly, although generally there are many associates moving about and feeding in an area. Individuals take materials carried along in the stream and rise to the surface to get floating objects.

TABLE IV

Food of 38 specimens of Notropis rubricroceus *collected from March 24 to Nov. 7*

Of 50 stomachs examined, 38 had food. Specimens were 52 to 64 mm. in standard length, one to five years old. Under each season the left column represents the percentage of stomachs with food, the right the percentage content of food by volume.

	Spring March 24–May 26		Summer June19–Sept. 16		Fall Sept. 20–Nov. 7		Total for three seasons				
							Stomachs with food		Vol. %	No. of organisms	
Stomachs, examined	14		22		14						
with food	13		13		12		No.	%		Total	Av. per stomach
Food item											
Aquatic Organisms	100.0	67.9	92.3	52.6	91.7	50.3	36	94.7	56.9	198	5.5
Terrestrial Organisms	69.2	29.2	92.3	45.9	100.0	47.2	33	86.8	40.8	95	2.9
Animals	100.0	88.4	100.0	90.8	100.0	88.8	38	100.0	89.3	272	7.2
Vegetation	46.2	9.5	30.8	7.7	58.3	8.8	17	44.7	8.7	21	1.2
Miscellany	53.8	2.8	30.8	1.4	25.0	2.5	14	36.8	2.2	16	1.1
Insecta	100.0	74.5	100.0	88.0	100.0	81.7	38	100.0	81.4	262	6.9
Ephemerida	61.5	28.8	92.3	23.3	91.7	33.0	31	81.6	28.4	89	2.9
Diptera	69.2	16.8	76.9	14.5	33.3	7.2	23	60.5	9.5	70	3.0
Trichoptera	38.5	9.2	69.2	18.4	50.0	8.9	20	52.6	12.2	33	1.7
Hemiptera	7.7	0.8	23.1	2.8	58.3	12.3	11	28.9	5.3	24	2.2
Hymenoptera	21.3	3.5	15.4	1.9	41.7	5.8	10	26.3	3.7	11	1.1
Coleoptera	7.7	2.3	30.8	6.0	33.3	14.6	9	23.7	7.6	9	1.0
Plecoptera	7.7	6.9	23.1	5.3			4	10.5	4.1	13	3.3
Lepidoptera	15.4	1.9	15.4	10.4			4	10.5	4.1	6	1.5
Megaloptera	7.7	3.5					1	2.6	1.2	1	1.0
Insect eggs			7.7	0.4			1	2.6	0.1	1	1.0
Insect remains	7.7	0.8	30.8	5.0			5	13.2	1.9		
Arachnoidea	15.4	0.6	7.7	2.8	25.0	7.1	6	15.8	3.5	7	1.2
Diplopoda	7.7	3.8					1	2.6	1.3	1	1.0
Oligochaeta	7.7	0.8					1	2.6	0.3	1	1.0
Algae	23.1	1.3	7.7	2.7	25.0	2.1	7	18.4	2.0		
Vascular plants	30.8	8.2	30.8	5.0	41.7	6.7	13	34.2	7.0		
Misc. residues	15.4	8.8	15.4	0.8	25.0	1.7	7	18.4	3.8		
Sand	46.2	2.1	23.1	0.6	8.3	0.8	10	26.3	1.2		

Factors influencing food eaten.—The large protrusile, obliquely terminal mouth; strongly hooked, sharp-pointed, raptorial pharyngeal teeth with finely serrate grinding surfaces; and relatively short digestive tract are suited to a carnivorous diet.

SUMMARY

The two species occur in the upper Tennessee River system. Members of *galacturus* are also present in tributaries of the Cumberland, White, and St. Francis rivers and have been taken in the Kanawha, Santee, and Savannah systems.

Individuals and small schools are active in the middle to upper levels of small to medium-sized mountain streams having fairly clear water, moderate current, and gravel or coarse sandy bottoms. They are more abundant near riffles, *galacturus* in the deeper and *rubricroceus* the somewhat shallow pools. Associates include fishes commonly found at moderate elevations in southern mountain streams west of the Blue Ridge.

Males generally equal or slightly exceed females of the same year class in length and have longer pelvic fins. During the spawning season, mature males have more pronounced coloration, and slightly prolonged snout. Tubercles are well-developed along the dorsal surface of the pectoral fin rays and moderately large on the snout and head of *galacturus*, enlarged and recurved medially on the upper surface of the prominent pectoral fin rays in *rubricroceus*.

Individual males of *galacturus* held territories under submerged surfaces as the projecting edge of a boulder and a floating tree limb where spawning occurred from May 25 to June 28 at water temperatures from 75° to 82°, air 84° to 89°F. Nests had 127 to 382 eggs.

Males of *rubricroceus* held territories over gravel nests of *Hybopsis micropogon* from as early as May 12 with spawning over the same area from May 25 to July 21 at water temperatures from 66° to 86°, air 67° to 90°F.

In formalin, mature eggs with the chorion were about 1.6 mm. in diameter. In the spring, the ovaries of large females of *galacturus* contained 404 to 1815 mature eggs, *rubricroceus* 445 to 1174. Larvae of *galacturus* hatched in the laboratory measured from about 5.2 mm. to 5.5 mm. in total length.

The scales of *galacturus* are broadly oval with the posterior margin deeply rounded to bluntly pointed. Those of *rubricroceus* are in the form of a broadly rounded shield. Members of *galacturus* seemed to form the annulus about or shortly after the middle of April; *rubricroceus*, the latter part of April.

Greatest growth occurred during the spring. Most individuals attained maturity when about two years old. They are short lived, and relatively few survive beyond the third summer.

Animal matter, largely insects, was the principal food. The protrusile, terminal mouth; sharp-pointed, raptorial pharyngeal teeth; and rather short alimentary tract are characteristic of predominantly carnivorous fishes.

LITERATURE CITED

COCKERELL, T. D. A., AND OTIS CALLAWAY. 1909. Observations on the fishes of the genus *Notropis*. Proc. Biol. Soc. Wash. (1909) **22:** 189–196.

COPE, EDWARD D. 1867. On the genera of fresh-water fishes *Hypsilepis* Baird and *Photogenis* Cope, their species and distribution. Proc. Acad. Nat. Sci. Philadelphia (1867) **19:** 156–166.

———. 1869. On the distribution of fresh-water fishes in the Allegheny region of south-western Virginia. Jour. Acad. Nat. Sci. Philadelphia (ser. 2) **6:** 207–247.

EVANS, HOWARD E. 1950. Structural modifications correlated with feeding habits in four species of cyprinid fishes. Cornell Univ. Thesis (Ph.D.). Ithaca, N. Y., 107 pp.

EVERMANN, BARTON WARREN. 1918. The fishes of Kentucky and Tennessee: a distributional catalogue of the known species. Bull. U. S. Bur. Fish. (1915–1916) **35:** 295–368.

GIBBS, ROBERT H., JR. 1957. Cyprinid fishes of the subgenus *Cyprinella* of *Notropis*. I. Systematic status of the subgenus *Cyprinella*, with a key to the species exclusive of the *lutrensis-ornatus* complex. Copeia 1957 (3): 185–195.

GREELEY, JOHN R. 1935. Fishes of the watershed with annotated list. *In* A biological survey of the Mohawk-Hudson watershed. Suppl. Ann. Rept. N. Y. St. Conserv. Dept. (1934) **24:** 63–101.

GÜNTHER, ALBERT. 1868. Catalogue of the Physostomi. . . . Cat. Fishes British Mus. **7:** xx + 512 pp.

HANKINSON, THOMAS L. 1930. Breeding behavior of the silverfin minnow, *Notropis whipplii spilopterus* (Cope). Copeia 1930 (3): 73–74.

JORDAN, DAVID STARR. 1876. Manual of the Vertebrates of the Northern United States.

. . . [1st ed.] Chicago: Jansen, McClurg and Co., 342 pp.

———. 1877. A partial synopsis of the fishes of upper Georgia; with supplementary papers on the fishes of Tennessee, Kentucky, and Indiana. Ann. New York Lyc. Nat. Hist. (1876 [1874–1877]) **11:** 307–377.

———. 1878. A catalogue of the fishes of the fresh waters of North America. Bull. U. S. Geol. and Geogr. Surv. Terr. (1878) **4:** 407–442.

———. 1880. Manual of the Vertebrates of the Northern United States. . . . 3rd ed. Chicago: Jansen, McClurg and Co., 406 pp.

———. 1885. A catalogue of the fishes known to inhabit the waters of North America, north of the Tropic of Cancer, with notes on the species discovered in 1883 and 1884. Rept. U. S. Comm. Fish and Fish. (1885) **13:** 789–973. (Also U. S. Govt. Printing Office 1885: 1–185.)

JORDAN, DAVID STARR, AND ALEMBERT W. BRAYTON. 1878. Contributions to North American ichthyology. Based primarily on the collections of the United States National Museum. III. A. On the distribution of the fishes of the Alleghany region of South Carolina, Georgia, and Tennessee, with descriptions of new or little known species. Bull. U. S. Natl. Mus. **12:** 3–95.

JORDAN, DAVID STARR, AND HERBERT E. COPELAND. 1876. Check list of the fishes of the fresh waters of North America. Bull. Buffalo Soc. Nat. Sci. (1875–1877) **3:** 133–164.

JORDAN, DAVID STARR, BARTON WARREN EVERMANN, AND HOWARD WALTON CLARK. 1930. Check list of the fishes and fishlike vertebrates of North and Middle America north of the northern boundary of Venezuela and Colombia. Rept. U. S. Comm. Fish. (1928) Pt. 2: iv + 670 pp.

JORDAN, DAVID STARR, AND CHARLES H. GILBERT. 1882. A synopsis of the fishes of North America. Bull. U. S. Nat. Mus. (1882) **16:** lvi + 1018 pp.

KIRSCH, PHILIP H. 1893. Notes on a collection of fishes from the southern tributaries of the Cumberland River in Kentucky and Tennessee. Bull. U. S. Fish Comm. (1891) **11:** 259–268.

MEEK, SETH EUGENE. 1894. Report of investigations respecting the fishes of Arkansas, conducted during 1891, 1892, and 1893, with a synopsis of previous explorations in the same state. Bull. U. S. Fish Comm. (1894) **14:** 67–94.

OUTTEN, L. M. 1956. Studies of the life history of the cyprinid fishes *Notropis coccogenis*, *galacturus*, and *rubricroceus*. Cornell Univ. Thesis (Ph.D.). Ithaca, N. Y., vi + 143 pp. (Multilithed).

———. 1957. A study of the life history of the cyprinid fish *Notropis coccogenis*. Jour. Elisha Mitchell Sci. Soc. **73:** 68–84.

RANEY, EDWARD C. 1947a. Subspecies and breeding behavior of the cyprinid fish, *Notropis procne* (Cope). Copeia 1947 (2): 103–109.

———. 1947b. *Nocomis* nests used by other breeding cyprinid fishes in Virginia. Zoologica **32:** 125–132.

ROBINS, C. RICHARD, AND RONALD W. CRAWFORD. 1954. A short accurate method for estimating the volume of stream flow. Jour. Wildl. Mgt. **18:** 366–369.

STONE, UDELL B. 1941. Studies on the biology of the satinfin minnows, *Notropis analostanus* and *Notropis spilopterus*. Cornell Univ. Abstr. of Theses (1940): 288–290.

THE YELLOW-LIPPED SNAKE, *RHADINAEA FLAVILATA* COPE, IN NORTH CAROLINA

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The Yellow-lipped Snake was originally described on the basis of a single specimen collected on Bogue Bank, about eight miles south of Fort Macon, Carteret County, North Carolina (Cope, 1871). Only eight specimens in addition to the type have been taken in North Carolina. One was collected near Councils, Bladen County, on July 9, 1915 (Schmidt, 1916), two were found on Shackleford Bank and four on Harker's Island, Carteret County, in 1939 (Engels, 1952), and another was secured on Shackleford Bank on August 21, 1948 (Robertson and Tyson, 1950).

New Hanover County, North Carolina, is located in the southeastern corner of the State and forms a peninsula bounded on the east by the Atlantic Ocean and on the west by the Cape Fear River. The lower half of this peninsula has a surface layer composed of almost pure white, fine-grained sand. The dominant vegetation of this sand consists of longleaf pine (*Pinus palustris*), turkey oak (*Quercus laevis*), and blackjack oak (*Q. marilandica*). A few characteristic herbs and clumps of wire grass (*Aristida stricta*) constitute the sparse ground cover.

Scattered throughout this sandy peninsula are many low, poorly drained, upland bogs or "pocosins" where water stands during much of the year. These bogs are overgrown with dense thickets of yaupon (*Ilex glabra*) and wax myrtle (*Myrica cerifera*) thickly interwoven with vines of various species. In these bogs reptiles and amphibians are abundant, but owing to the nature of the plant cover, they are exceedingly difficult to secure.

Mr. George Tregembo, Wilmington, North Carolina, a dealer in natural history items, has many assiduous collectors who supply him with reptiles and amphibians. During the past five years they have collected hundreds of reptiles in the lower Cape Fear region, and much of their collecting has been done in this sandy section of New Hanover County. They never found *Rhadinaea*, however, until May 7, 1956, when an adult male was taken near the tip of the peninsula. On May 11, another male and a gravid female were taken about five miles north of the place where the first specimen was collected. Subsequently many of these snakes have been found within this same area. Most of these snakes were found under objects lying in contact with damp sand.

Two of these snakes, including the gravid female, were kept in captivity during the summer of 1956 by the author. They fed readily on cricket frogs (*Acris gryllus*). Malnate (1939) witnessed the method of feeding by *Rhadinaea* on the chameleon (*Anolis carolinensis*), in which the snake remained hidden until the lizard approached within striking distance. The two snakes mentioned above also remained hidden under rocks in the terrarium. During daylight hours they lay under a rock with only the head protruding, but moved about actively at night. When a cricket frog came within range of the hidden snake, it was immediately seized and pulled under the rock. Usually the frog was turned in the jaws and swallowed head first. On one occasion, however, a frog was seized directly in front of the hind legs and swallowing began immediately. The legs were forced up alongside the body as swallowing progressed, so that the head and hind feet disappeared simultaneously. These two snakes did not appear to imbed the posterior teeth and wait for a mild venom to numb the prey, as Neill (1954) observed, but swallowed the frogs immediately.

During the night of June 4, 1956, the female laid four eggs in a non-adherent cluster under a rock in the terrarium. They were white with a leathery surface irregularly covered with wavy, longitudinal ridges. The surface appeared granular to the unaided eye, but distinctly ridged when observed under a binocular microscope. The eggs were 13 mm. in length and 5 mm. in diameter. Eggs of this species measured by Allen (1939) were much larger, being 23 mm. by 8 mm.

LITERATURE CITED

Allen, E. Ross. 1939. Habits of *Rhadinaea flavilata*. Copeia **3**: 175.

Cope, E. D. 1871. Proc. Acad. Nat. Sci. Phila. **23**: 222–223.

Engels, William L. 1952. Vertebrate fauna of North Carolina coastal islands. II.

Shackleford Banks. Amer. Midland Naturalist **47:** 702–742.

MALNATE, EDMOND. 1939. A study of the Yellow-lipped Snake, *Rhadinaea flavilata* (Cope). Zoologica **24:** 359–366.

NEILL, WILFRED T. 1954. Evidence of venom in snakes of the genera *Alsophis* and *Rhadinaea*. Copeia **1:** 59–60.

ROBERTSON, WILLIAM B. AND EDWIN L. TYSON. 1950. Herpetological notes from eastern North Carolina. Jour. Elisha Mitchell Sci. Soc. **66:** 130–147.

SCHMIDT, K. P. 1916 Herpetology of North Carolina. Jour. Elisha Mitchell Sci. Soc. **32:** 33–37.

THE CONTROL OF REPEATED INFECTIONS WITH *TRICHINELLA SPIRALIS* IN MICE BY THE USE OF FEED CONTAINING CADMIUM OXIDE

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In a previous report (Larsh and Goulson, 1957), it was shown that medicated feed in pellet form containing 0.015 per cent cadmium oxide produced a striking reduction in the number of adults and larvae of *T. spiralis* recovered after a single infection, and an even greater reduction of adult worms after one reinfection. These results suggested that this chemical, as an additive to the daily feed, might be used to control trichinosis in swine. To serve this purpose, it would be necessary for the chemical to prevent, even after repeated infections, the encystment of large numbers of larvae in the musculature. Before making such determinations in swine, it seemed advisable to carry out the present study in the mouse host. So that the results would be most valuable in deciding the desirability of future tests in swine, these experiments were designed in an attempt to simulate conditions in nature whereby swine are exposed at intervals to infection with the parasite.

Materials and Methods

The experimental animals used in the study were Swiss white mice of a stock strain maintained by this Department. The various experimental procedures were, with only minor changes, those described in earlier reports (Larsh and Kent, 1949; and others). The diets (in pellet form with 0.015 per cent cadmium oxide, and non-medicated pellets for controls) were supplied by Pitman-Moore Co., New Augusta, Indiana, through the courtesy of Dr. G. R. Burch.

Statistical analysis of the observed differences in numbers of parasites recovered from the various groups of mice was performed by means of Student's "t"-test. A probability greater than 0.05 was not considered significant.

Experimental Procedures and Results

One-hundred-twenty-eight mice, 12 weeks old, were matched according to sex and approximate weight and divided into three groups (Table 1). The 48 mice of Group I (experimentals) received the medicated feed (0.015 per cent cadmium oxide) from 48 hours before the first infection until necropsy. The 48 mice of Group II (infected controls) received the same feed without medication for the same periods, as was the case for the 32 mice of Group III (non-infected controls). Forty-eight hours after introducing the test feeds, all of the mice of Groups I and II were given an infection with 200 *T. spiralis* larvae. The mice of Group III were not infected at this time.

Seven days after infection, eight mice of Group I and the same number from Group II were sacrificed and counts were made of the number of adult worms in the small intestine. Thirty days after infection, eight mice from each of the two groups were sacrificed and counts were made to estimate the total number of larvae in the musculature.

Twenty-one days after the first infection, the remaining mice in Groups I and II (32 in each) were given a second infection with 300 larvae. To determine whether or not immunity had been developed as a result of the first infection, it was necessary to give the same infection to mice not infected previously. Sixteen mice of Group III served this purpose. At 7 days after infection, eight mice from each of the three groups were sacrificed for adult worm counts, and at 30 days after infection a like number from each group was sacrificed to determine the estimated number of larvae in the musculature.

Twenty-one days after the second infection, the remaining mice in Groups I and II (16 in each) were given a third infection with 400 larvae. The remaining 16 mice of Group III were given the same infection for the reason explained above. One-half of the mice of each group was sacrificed at seven days after infection for adult worm counts, the other half was sacrificed 30 days after infection for counts of the larvae in the musculature.

Average worm counts of the various groups are presented in Table 1, and the results of the "t"-tests to determine the significant differences between certain counts are shown in Table 2.

At seven days after the first infection, the experimentals (Group I) had a significantly smaller average number of adult worms (53.1)

TABLE 1

The average number of T. spiralis *adults recovered from the small intestine 7 days after infection, and the average number of larvae recovered from the musculature 30 days after infection, from mice fed cadmium oxide and from controls*

For the counts of larvae, the numbers in parentheses indicate the ratio of recovered larvae to the total number of larvae administered in the infection(s).

Infection	Group I (Experimentals)				Group II (Infected controls)				Group III (Non-infected controls)			
	Medicated				Non-medicated							
	No. mice	Adults (per cent)	No. mice	Larvae (ratio)	No. mice	Adults (per cent)	No. mice	Larvae (ratio)	No. mice	Adults (per cent)	No. mice	Larvae (ratio)
I (200 larvae)	8	53.1 (26.6)	8	4,398 (22.0×; infection I)	8	121.8 (60.9)	8	27,818 (139.1×; infection I)				
	Medicated; one prior infection (I)				Non-medicated; one prior infection (I)				Non-medicated; not infected previously			
II (300 larvae given 21 days after infection I)	8	39.6 (13.2)	8	4,718 (9.4×; infections I, II)	8	145.8 (48.4)	8	31,032 (57.1×; infections I, II)	8	175.2 (58.4)	8	45,410 (151.4×; infection II)
	Medicated; two prior infections (I, II)				Non-medicated; two prior infections (I, II)				Non-medicated; not infected previously			
III (400 larvae given 21 days after infection II)	8	3.6 (0.9)	8	2,901 (3.2×; infections I, II, III)	8	137.4 (34.4)	8	32,000 (35.6×; infections I, II, III)	8	217.4 (54.4)	8	42,100 (105.2×; infection III)

TABLE 2

Selected counts of adult and larval worms compared for significant differences by means of the "t"-test

Infection	Comparisons by groups	Type	Standard error ($\bar{x}_1 - \bar{x}_2$)	"t" value	Degrees of freedom	Level of significance
I	I vs. II	adult	8.07	8.51	14	0.001
	I vs. II	larvae	4,717.94	4.96	14	0.001
II	I vs. II	adult	20.87	5.09	14	0.001
	II vs. III	adult	28.50	1.03	14	Not significant
	I vs. III	adult	25.16	5.39	14	0.001
	I vs. II	larvae	7,226.97	3.64	14	0.01
III	I vs. II	adult	18.21	7.35	14	0.001
	II vs. III	adult	24.25	3.30	14	0.01
	I vs. III	adult	16.66	12.83	14	0.01
	I vs. II	larvae	2,863.70	7.37	14	0.001

than the infected controls of Group II (121.8). Likewise, a significantly smaller average number of larvae was recovered from the Group I mice (4,398) than from the Group II mice (27,818).

At seven days after the second infection, the experimentals had significantly fewer adult worms (39.6) than the infected controls (145.8) and the non-infected controls (175.2). There is no signifi-

cant difference between the counts for the two control groups, indicating that the Group II mice failed to develop a demonstrable immunity as a result of the first infection. It should be added that four additional mice, "persistency controls," in Groups I and II were necropsied at this time to determine whether or not adult worms had persisted from the first infection given to Groups I and II. These special controls, not included in the total numbers of mice given above, had received the first infection but not the second infection. An average of less than two worms was recovered from these eight mice, hence, for practical purposes, it may be assumed that the average recoveries given above for the various groups were those from the second infection only. Similar findings resulted after the third infection, so no further mention of these special controls is needed.

As to the larvae counts, direct comparisons can be made only between groups receiving the same number of infections, since each infection may contribute to the number of muscle larvae. Thus, in this case, only the count for the experimentals (4,718) and that for the infected controls (31,032) can be compared. The former is significantly less than the latter. The Group III mice had an average of 45,410 larvae.

At seven days after the third infection, the experimentals had significantly fewer adult worms (3.6) than the infected controls (137.4) and the non-infected controls (217.4). In this case, the infected controls harbored significantly fewer adults (137.4) than the non-infected controls (217.4), showing that immunity had resulted from the two prior infections. The experimentals also harbored significantly fewer larvae (2,901) than the infected controls (32,000). The Group III mice had an average of 42,100 larvae.

DISCUSSION

It is clear from the above results that the experimental mice fed the medicated feed harbored significantly fewer *T. spiralis* adults and larvae than the controls (Tables 1 and 2). After the first infection, the average adult worm burden of the experimentals was 26.6 per cent of the infecting dose of 200 larvae, while that of the non-medicated group (infected controls) was 60.9. The respective average larval worm burdens were 22.0 and 139.1 times the number of larvae given at infection. These various averages compare favorably with those for comparable groups of mice in an earlier study (Larsh and Goulson, 1957). Since none of the mice had been infected previously, the significant reductions in the worm burdens of the experimentals can be attributed entirely to the action of the chemical.

After the second infection, however, the combined effect of the chemical action and that of acquired immunity must be considered, since one infection stimulates such immunity (Larsh and Race, 1954; Larsh *et al.* 1956). The average adult worm burden of the experimentals was 13.2 per cent of the infecting dose of 300 larvae, compared with 48.4 per cent for the infected controls and 58.4 per cent for the non-infected controls. Since the latter two counts do not differ significantly, it would appear on the basis of this criterion alone that the infected controls had not developed a demonstrable immunity from the stimulation of the first infection. However, their burden of muscle larvae (31,032) was considerably less after the two infections than that (45,410) of the non-infected controls after a single infection. There is evidence that in the presence of a feeble acquired immunity, insufficient to cause a significant reduction in adult worms within seven days after infection, the number of muscle larvae may be reduced as the result of actions against the adult females in the intestine (Campbell, 1955; Chipman, 1957). Thus, it would appear that the infected controls had developed a feeble immunity as a result of the first infection. It follows that the experimentals, given the same infection, developed a similar degree of immunity from this stimulation. In view of this, the striking reduction in the number of worms recovered from them after the second infection must be attributed to the combined effect of the immunity and the anthelmintic action of the chemical. No other interpretation is apparent, since the effectiveness of the chemical alone would not be expected to be increased strikingly merely as the result of extending the period of its administration from 48 hours prior to infection (first infection) to 23 days prior to infection (second infection).

After the third infection, the average adult worm burden of the experimentals was only 0.9 per cent of the infecting dose of 400 larvae, compared with 34.4 per cent for the infected controls and 54.4 per cent for the non-infected controls. In this case, the latter two counts differ significantly, showing that the infected controls had developed a demonstrable immunity from the two previous infections. Thus, in the experimen-

tals the combined effect of the immunity and action of the chemical, much greater than after two infections, must have been due mainly to the increased immunity. It would appear that as the immunity increased, its direct effect(s) upon the worms made them more susceptible to the chemical. If this is the case, it should be possible in time to prevent reinfection entirely in mice kept on the medicated feed and exposed at intervals to the parasite. Evidence for this was obtained by the failure to recover any worms from some of the experimentals after the third infection.

It is of interest to note the results of the various counts of muscle larvae (Table 1). Despite reinfections with increased numbers of larvae, the infected controls showed only a small increase in the average total number of larvae in the musculature. Thus, after the third infection, making a total of 900 larvae given in the three infections, the number of muscle larvae (32,000) was about the same as that (27,818) following the first infection with 200 larvae. Moreover, the 32,000 total larval worm burden was more than 10,000 less than that of the non-infected controls after a single infection with 300 or 400 larvae. An even more striking degree of immunity, as measured in this way, is illustrated by the counts for the experimentals. In this case, however, the last count is lower than the previous two. Although this can not be explained, there is a possibility that it resulted from the long-continued feeding of the chemical. In the absence of such a chemical, as existed in the infected controls in the present case, evidence favors the view that after repeated infections the number of muscle larvae fails to increase proportionately because of actions against the females in the intestine causing their early elimination or reducing their reproductive potential. Perhaps after long periods, a chemical of this type may destroy some encysted larvae, or produce changes making it impossible to recover them after muscle digestion.

The present results indicate that, in the mouse host at least, trichinosis can be controlled effectively by the addition of cadmium oxide in the feed, provided the exposures to infection are moderate in degree and are spaced at intervals. These results, as well as those of an earlier study in mice (Larsh and Goulson, *loc. cit.*), make it possible to consider the control of this parasite in the important animal reservoir, the hog. If, as seems likely, acquired immunity develops in swine at a rate comparable to, or greater than, that demonstrated in the mouse host, the combined effect of the immunity and the chemical probably would have a similar inhibiting effect upon the parasite. If so, the degree of muscle invasion could be kept at a low level despite repeated moderate infections, thereby protecting the health of the swine and minimizing the danger of severe clinical cases of human trichinosis. In view of this, it was decided to proceed with tests to determine the effectiveness of this chemical in swine trichinosis.

SUMMARY

The continuous use of a medicated feed in pellet form, containing 0.015 per cent cadmium oxide, produced a striking reduction in the number of adults and larvae of *T. spiralis* recovered from mice after a single infection. An even greater effect was shown after two, and after three, successive infections, indicating that the reductions were due to the combined effect of acquired immunity and the anthelmintic action of the chemical. The results encourage the testing of this chemical against *T. spiralis* in swine, since its use in feed may provide a practical means of controlling the disease in this important reservoir.

LITERATURE CITED

CAMPBELL, C. H. 1955. The antigenic role of the excretions and secretions of *Trichinella spiralis* in the production of immunity in mice. Jour. Parasitol. **41:** 483–491.

CHIPMAN, P. B. 1957. The antigenic role of the excretions and secretions of adult *Trichinella spiralis* in the production of immunity in mice. Jour. Parasitol. **43:** 593–598.

LARSH, J. E. JR., AND H. T. GOULSON. 1957. The effectiveness of cadmium oxide against *Trichinella spiralis* in mice. Jour. Parasitol. **43:** 440–445.

———, AND D. E. KENT. 1949. The effect of alcohol on natural and acquired immunity of mice to infection with *Trichinella spiralis*. Jour. Parasitol. **35:** 45–53.

———, AND G. J. RACE. 1954. A histopathologic study of the anterior small intestine of immunized and nonimmunized mice infected with *Trichinella spiralis*. Jour. Inf. Dis. **94:** 262–272.

———, ———, AND W. B. JEFFRIES. 1956. The association in young mice of intestinal inflammation and the loss of adult worms following an initial infection with *Trichinella spiralis*. Jour. Inf. Dis. **99:** 63–71.

AN UNUSUAL ALGAL HABITAT[1]

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On July 7, 1958 the author made several algal collections from a roadside ditch two miles East of Dover, North Carolina. The water was clear and had a slight current. Its temperature was 31°C. and its pH was 5.4. The ditch's banks were choked with various weeds and in the water was an abundant growth of *Utricularia vulgaris* L. It was growing in 5 inches of slowly moving water and lined both sides of the four foot wide channel. As a matter of course, the *Utricularia* was collected and brought to the laboratory where it was examined in the living condition for possible algal epiphytes.

In order to flatten a preparation for easier viewing, the cover slip was pressed quite heavily with a dissecting needle. Fortunately, as this was done, the writer was observing one of the *Utricularia* bladders when suddenly it expelled a mass of algal cells—mostly desmids. This procedure was repeated with other bladders, some from the same plant and some from other plants. In every case they yielded at least a few cells. After many examinations it became apparent that about half of the bladders contained less than ten algal cells. The remaining fifty per cent yielded a great number of cells. To add to the interest, approximately one out of every ten bladders liberated numbers that were astounding.

To gain some idea of the numbers, kinds, and percentages, ten bladders were chosen at random from several plants. Each was placed in a drop of tap water on separate slides, covered, and then squeezed. The slides were examined and the individuals counted. Table 1 represents the results.

Further investigation revealed that only eleven species accounted for over ninety per cent of the populations. They were **Arthrodesmus octocornis* Ehrenberg, *Closterium leibleinii* Kuetzing, **Cosmarium subtumidum* Nordstedt, **Euastrum leutkemueller* Ducellier, **Euastrum elegans* var. *ornatum* West and G. S. West, *Gymnozyga moniliformis* Ehrenberg, *Penium margaritaceum* (Ehrenb.) Brébisson, **Scenedesmus hystrix* Lagerheim, **Staurastrum apiculatum* Brébisson, **Staurastrum margaritaceum* (Ehrenb.) Meneghini, and **Staurastrum quadrispinatum* var. *spicatum* forma *furcatum* Scott and Grönblad. Of these eleven taxa, the eight marked with asterisks represent new additions to the fresh-water algae of North Carolina.

TABLE 1

10 slides—each with 1 bladder

Genera	Slides 1–5	Slide 6	Slide 7	Slide 8	Slide 9	Slide 10
Arthrodesmus	Less than ten organisms.	—	3	—	6	2
Closterium		1	3	2	21	6
Cosmarium		3	3	2	19	8
Euastrum		1	1	—	11	2
Gymnozyga		—	2	—	1	—
Penium		—	2	—	1	1
Scenedesmus		1	1	3	15	7
Staurastrum		5	28	19	245	38
Total		11	43	26	319	64

(Average size of the 10 bladders = 1.58 mm x 1.15 mm.)

Subsequent examinations of *Utricularia floridosa* Walt. and *Utricularia purpurea* Walt. from other localities revealed similar though less startling results. However, one bladder of *U. purpurea* was most noteworthy for it contained eleven genera of desmids—*Arthrodesmus*, *Cosmarium*, *Docidium*, *Euastrum*, *Gymnozyga*, *Micrasterias* *Penium*, *Pleurotaenium*, *Staurastrum*, *Triploceras* and *Xanthidium*. Again, several new state records were obtained, i.e. *Docidium undulatum* var. *perundulatum* West and G. S. West, *Staurastrum ornithopodum* West and G. S. West, and *Xanthidium antilopaeum* var. *floridense* Scott and Grönblad.

Practically all of the species found in the various bladders were also found in the surrounding

[1] This work was done at the Botany Dept., North Carolina State College, Raleigh, while under a temporary appointment. The research was supported by Contract No. At-(40-1)-2100 with the Atomic Energy Commission's Div. of Biology and Medicine.

waters, but in fewer numbers. In fact, most of them appeared only on rare occasions in the surrounding medium. It is probable the slight currents washed many of these forms away and kept their populations at a minimum. However those chance wanderers that found their way into a bladder were fortunate in finding environmental conditions approaching the ideal. Here they flourished and multiplied in numbers. Lloyd, in studying the mechanism of the *Utricularia* trap, noted the presence of desmids and offered the opinion that there appears to be no evidence of obligate relations. Whether or not the bladders in this study gave the algae more than simple physical protection is not known, but it does present an intriguing physiological and ecological question.

From the above results, it seems apparent that algal investigators should collect and examine the bladders of *Utricularia* with the possibility of repeating the author's good fortune.

ACKNOWLEDGMENTS

The author wishes to acknowledge the aid and facilities offered by E. O. Beal, L. A. Whitford and the Botany Department, North Carolina State College, Raleigh.

LITERATURE CITED

LLOYD, F. E. 1942. The Carnivorous Plants. Chronica Botanica Co., Waltham, Mass.

PHILLIPS, R. C. AND L. A. WHITFORD. 1958. Additions to the fresh-water algae in North Carolina II. Castanea **23**: 25–30.

PRESCOTT, G. W. 1948. Desmids. The Bot. Rev. **14**: 644–676.

TIFFANY, L. H. 1938. Algae, the grass of many waters. Chap. IX. Charles C. Thomas, Springfield, Ill.

WHITFORD, L. A. 1943. The fresh-water algae of North Carolina. Jour. Elisha Mitch. Sci. Soc. **59**: 131–170.

———. 1956. Additions to the fresh-water algae in North Carolina I. Trans. Amer. Micros. Soc. **75**: 196–203.

PHYTOPLANKTON IN NORTH CAROLINA LAKES AND PONDS[1]

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In spite of the fact that the plankton algae have been extensively investigated in Europe and in northern United States and Canada, there has been relatively little work on this ecological group in the southeastern states. While plankton species have been reported in many taxonomic and floristic studies (Bailey 1851, Poteat 1888, Prescott and Scott 1942, 1945, 1952, Whitford 1936, 1943, 1956, *et al.*) the only papers dealing with abundance and seasonal distribution are those of Eddy 1930, Harris and Silvey 1940, and Schumacher 1956. The first is a rather restricted study of Reelfoot Lake, Tennessee. Both geology and flora indicate that the affinities of this lake are more with the midwest than the southeast. Harris and Silvey's study of four Texas reservoir lakes is in a region not in the southeast, but on the prairie border. Therefore, only the area studied by Schumacher is comparable to that of the present paper. He collected over a period of a year in fifteen ponds in the Coastal Plain of southeastern Georgia. This study indicated some differences between the phytoplankton of the southeast and other areas of this continent which have been studied. He found rather marked differences in numbers of species and dominant groups in the ponds of this small area. He describes three types of ponds, (1) a group low in bulk of phytoplankton but having a large number of species rather evenly distributed throughout the year, (2) a group having a large number of desmid species, rich in numbers and "exhibiting marked seasonal pulsations," and (3) a group high in diatoms and blue-green algae.

Description of the Area

North Carolina is divided into three physiographic regions, the Coastal Plain, Piedmont, and Mountains. The surface of the Coastal Plain consists of Recent to Mesozoic sands and loams with some clays, and ranges in elevation from sea level to 120 meters (400 ft.). Its inner border is marked by the towns of Roanoke Rapids, Smithfield and Wadesboro. It covers 40% of the area of the state. Considerable deposits of peat occur near the coast. These range from nearly pure peat in low areas to peat soil mixtures with as little as 20% peat at slightly higher elevations. In the lower Coastal Plain, hundreds of natural shallow lakes and ponds occur. Coastal Plain lakes and ponds fall into two types: (1) shallow waters (2–3 meters) over sand or loam soils with the same type of watershed. Many are water-table ponds that at times become completely dry. (2) Brown-water ponds and lakes (including the largest water areas in the Coastal Plain) are also shallow (1–3 meters). These are found over sand or sandy peat with run-off from bog areas containing much shrub peat. Some are "Carolina Bay" lakes and some are former estuaries only a few feet above sea level. The waters of the Coastal Plain are low in minerals, and always acid. The pH ranges from 4.2 to about 6.0 .

The Piedmont region is a rolling plateau with red clay soils, or sandy loam over slate and shales. It covers about 40% of the state and extends from the Coastal Plain to the mountains. The towns of Mount Airy, Marion, and Tryon mark its inner border. In elevation, it ranges from 120 meters (400 ft.) to about 500 meters (1,600 ft.) above sea level. There are numerous outcrops of gneiss and granite with some of slate and shales mostly of Proterozoic age.

Mountains occupy about 20% of the area of the state and are higher than any other area in the Appalachians. Valleys range in elevation from 600 meters (2,000 ft.) to about 1,200 meters (4,000 ft.). The rocks here also are mostly Proterozoic.

Lakes and ponds in the Piedmont and Mountains are all artificial. There are 20 fairly large lakes and reservoirs and hundreds of small ponds. There are a few ponds about 1,200 meters in elevation, but most lie between 700 and 800 meters. Most lakes and reservoirs are below 600 meters in elevation. Water areas vary in size from less than 1 hectare (½ acre) to power reservoir lakes several kilometers (1–1½ miles) wide and up to 30 km. (20 miles) in length. Their depth is also quite variable but never deep. Most of the ponds average about 1–3 meters in depth while

[1] This work was aided by Contract No. AT-(40-1)-2100 with the Atomic Energy Commission's Division of Biology and Medicine.

TABLE I

Average analysis of streams in the Mountains (74 streams), Piedmont (35 streams), and the Coastal Plain (16 streams)

The Brown water stream is Lumber River, Robeson County. The analyses show somewhat greater turbidity, suspended matter, etc. than would be true of lakes and ponds, but several recent analyses of pond and lake waters show them to be otherwise closely comparable.

	Mtns.	Pied.	C. Plain	Brown water
Silicate	10.0	16.0	13.0	15.2
Iron	0.21	0.81	0.60	0.40
Calcium	2.4	5.2	4.7	2.5
Magnesium	1.0	1.9	1.9	1.5
Sodium	2.2	4.2	5.4	2.3
Potassium	0.58	0.98	1.1	0.5
Carbonate	0.0	0.0	0.0	0.0
Bicarbonate	12.0	21.0	21.0	13.0
Sulfate	2.4	5.9	4.9	2.1
Chlorine	1.9	4.6	7.8	4.0
Nitrate	0.33	0.83	0.60	0.3
Dissolved solids	31.0	62.0	57.0	43.9
Hardness	10.0	20.0	19.0	12.4
Color	14.0	31.0	34.0	70.0
Turbidity	34.0	102.0	66.0	11.0
Suspended matter	11.0	61.0	48.0	20.0
Alkinity	11.0	18.0	15.0	12.0

parts of some reservoirs may be 15 to 20 meters deep.

In the Piedmont the water of lakes and ponds is always more or less turbid with colloidal clay so that light penetration is poor. It is clearest following periods of dry weather in summer but Secchi disk readings are less than one meter even then. Except for farm ponds the water is low in minerals. The pH ranges from 6.6 to 7.2 in the Piedmont and from 6.4 to 6.6 in the Mountains. In the Mountains the waters are clearest especially where the watershed is forested.

Climate

The state lies chiefly between 34–37° N. latitude, therefore the climate is moderate. Nevertheless it is the most varied of any state east of the Rocky Mountains. This is due to the influence of the ocean in the east and the fairly high mountains in the west. The western range of mountains averages close to 1,500 meters (5,000 ft.) in elevation, and the high valleys are cold, but this ridge also has a moderating effect on the area eastward by blocking cold air masses from the west in winter. The average annual temperature is 15°C (59°F) but there is a variation from 10°C in the mountains to 17°C (62°F) at the coast. Freezing temperatures during daylight hours are rare along the coast and only in high mountain valleys do ponds remain frozen even for a few days in winter. Freshwater algae grow the year round in the Coastal Plain and most of the year in the Mountains. Frost free days per year vary from 150 in mountain valleys to over 250 days at the coast.

The rainfall is average and most of it comes during the growing season. Precipitation averages 127 centimeters (50 ins.) but varies from 94 to 203 cm.

Methods

This paper reports a study of the relative abundance and seasonal relations of the net phytoplankton together with some observations on the nannoplankton, and counts of organisms in some areas. Most of the collecting was done during the past ten years, but some as long as 20 years ago. Except for a three months study of farm ponds, only lakes and ponds over five years old and as little affected by agricultural practices as possible were sampled. The number of collections approximates 1,000 made at all seasons and in all regions of the state, although relatively fewer were made in the Mountains than other areas.

Most of the records are from a "standard tow" of about ten meters (30 ft.) with a 23 centimeter (9 ins.) No. 20 silk plankton net in the surface meter of the open water. About 60% of the samples were examined fresh within a few hours after collection. All were examined later after preservation in Transeau's solution (6 parts water, 3 parts 95% alcohol, 1 part formalin). Three drops of the shaken collection were examined under a large cover glass at 100 and 400 diameters magnification and all species present noted. Then a careful visual estimate was made of those forms making up 80% or more of the bulk of the phytoplankton, and the dominants listed in order of abundance. In most cases this was easy, but in sparse collections from extremely oligotrophic situations, the first five species only were listed in order of abundance.

The data given are largely from these examinations. The curves in Fig. 1 are based on this method and show relative abundance and not

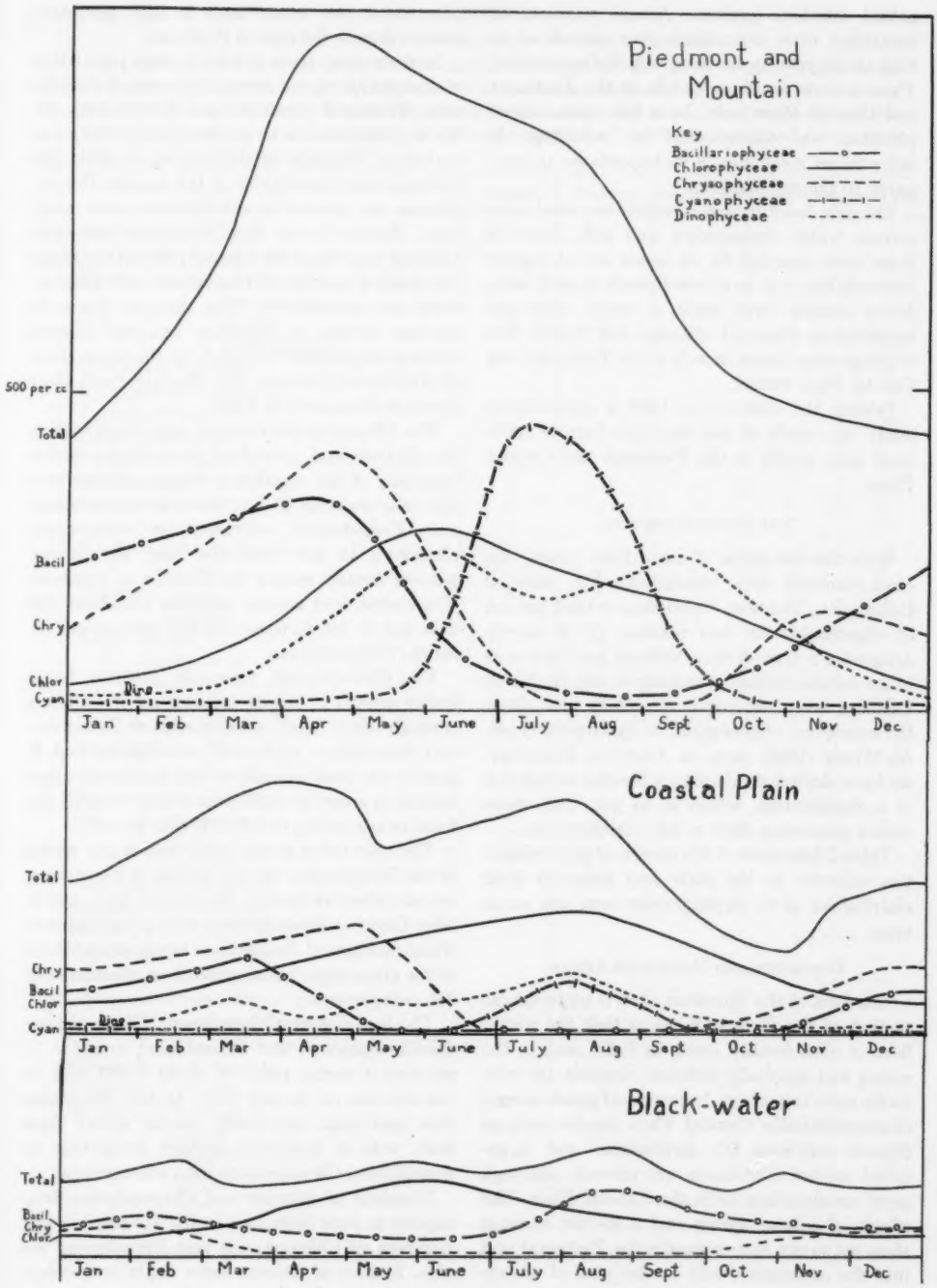
Piedmont and Mountain
Key
Bacillariophyceae
Chlorophyceae
Chrysophyceae
Cyanophyceae
Dinophyceae
500 per cc
Total
Bacil
Chry
Chlor
Cyan
Dino
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
Coastal Plain
Total
Chry
Bacil
Chlor
Cyan
Dino
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
Black-water
Total
Bacil
Chry
Chlor
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec

FIGURE 1

actual numbers present. Actual numbers of organisms were determined over periods of as long as one year by the Sedgwick-Rafter method. These counts are from ponds in the Piedmont and Coastal Plain only. In a few cases nannoplankton was concentrated by centrifuge in order to get some idea of its importance as compared to the net plankton.

The only habitat factors widely recorded were surface water temperature and pH. None of these were recorded for all ponds nor at regular intervals but only in selected ponds in each area. Many records were made of water color and turbidity as observed visually, but Secchi disk readings were taken in only a few Piedmont and Coastal Plain waters.

During the summer of 1948 a comparative study was made of the plankton flora of fertilized farm ponds in the Piedmont and Coastal Plain.

THE PHYTOPLANKTON

With the exception of some farm ponds, the phytoplankton flora throughout the state is Caledonian. The term Caledonian is used instead of oligotrophic for two reasons; (1) it merely designates a type of flora without implication as to the habitat factors producing it, and (2) North Carolina lakes and ponds do not fit into either the eutrophic, oligotrophic, or dystrophic types. As Welch (1952) says, in American limnology, we have drifted slowly into a limited acceptance of a classification, which is, as yet, little more than a pioneering effort at lake classification.

Table 2 lists most of the species of phytoplankton collected in the state and indicates their distribution as to physiographic area and water type.

PIEDMONT AND MOUNTAIN AREAS

The flora of the Mountain area is quite similar to that of the Piedmont except that the winter flora is considerably lower in bulk, and in the spring and especially summer, desmids are relatively more important. In more acid ponds several characteristically Coastal Plain species such as *Synura petersenii* (*C. caroliniana*) and large-celled species of desmids are present, although never as abundant as in the Coastal Plain. The effects of a later spring and a shorter summer show up, as one moves west in the Piedmont and into the mountains, only in the time of abundance of major groups. The spring maximum occurs about two weeks later in high mountain valleys than in the central Piedmont.

In these areas there is a fairly large population of diatoms all winter. Several varieties of *Synedra ulna*, *Tabellaria fenestrata* and *T. flocculosa* are the important forms. In smaller ponds, with lower turbidity, numbers of diatoms may reach 200 cells per cubic centimeter at this season. *Chrysophyceae* are present in considerably lower numbers. *Synura uvella* and *Dinobryon sertularia* together may reach 50 colonies per cc. Occasional small-celled species of *Cosmarium* and *Staurastrum* are encountered. The diatoms begin to increase slowly in February and the diatom curve is augmented in March by the appearance of *Asterionella formosa*. The diatoms reach their greatest abundance in April.

The *Chrysophyceae* increase more rapidly than the diatoms and growth of these begins earlier especially if the weather is bright. *Mallomonas* spp. may make up 25% of the total in late winter and *Uroglenopsis americana* is occasionally abundant. In late April and May the *Chrysophyceae* usually exceed the diatoms in numbers. The spring, and annual, maxima are about 500 cells per cc. for diatoms and 600 colonies per cc. for the *Chrysophyceae*.

The *Chlorophyceae*, especially desmids, begin spring growth in March and increase in numbers through May. Small-celled species of *Cosmarium* and *Staurastrum* such as *C. moniliforme* and *S. gracile* are most abundant, but numerous other species in seven or eight genera help to swell the total in late spring to 600–800 cells per cc.

The only other group important in the spring is the *Dinophyceae*. Several species of *Peridinium* are abundant at times in March and April, and in May *Ceratium hirundinella* is widely encountered. Total numbers of *Dinophyceae* rarely exceed those of the green algae but may reach an abundance of 400 cells per cc.

The four classes, *Chlorophyceae*, *Chrysophyceae Bacillariophyceae*, and *Dinophyceae*, combine to produce a spring pulse of about 1,500 cells or colonies per cc. in mid May. In the Mountains this maximum apparently occurs about June first, with a somewhat greater proportion of desmids and *Chrysophyceae* than other groups.

Numbers of diatoms and *Chrysophyceae* drop rapidly in June (late June in the Mountains) and numbers of *Chlorophyceae* and *Dinophyceae* fall also. Species of *Chlorococcales* begin to increase at this time, however, and the curve for the

TABLE II

List of plankton species collected in North Carolina

A plus (+) indicates the presence of a species in a type of lake, pond or pool, and a letter indicates a species important in the plankton at the season indicated: w = winter; v = spring; s = summer; a = autumn. The column Small Pools includes fish-pools, shallow pools in fields and ditches, swamp pools, and pools in rocks. An asterisk (*) indicates fertilized farm ponds and (+″) rock pools above 4,000 ft.

	Mountain	Piedmont	Coastal Plain	Brown Water	Small Pools
CHLOROPHYCEAE					
Polyblepharides singularis					+
Chlamydomonas fenestrata					+
" *patellaria*					+
" *pertyi*	+	+	+	+	+
" *platystigma*					+
Lobomonas rostrata					+
Chlorogonium euchlorum			+		
Furcilia lobosa					+
Carteria globulosa					+
Pteromonas angulosa					+
Coccomonas orbicularis			+		
Gonium pectorale	+	+	+	+	+
" *sociale*		+			
Pandorina charkowiensis			+		
" *morum*	v	v	v	+	v
Eudorina elegans	+	v	+	+	+
" *unicocca*			+		
Volvox aureus		+			
" *dissipathrix*		+			
" *mononae*			+		
" *prolificus*					+
Haematococcus lacustris					vs
Stephanosphaera pluvialis					+″
Sphaerocystis schroeteri	+	+	+		
Heterodictyon planctonicum			+		
Gleocystis botryoides					+
" *gigas*	+	+	+		
" *vesiculosa*			+		
Asterococcus limneticus			+		
Elakatothrix gelatinosa			+		
Nannochloris bacillaris					+
Chlorococcum humicola					+
Golenkinia radiata					+
Dictyosphaerium ehrenbergianum			+		
" *planctonicum*			+		
" *pulchellum*	+	v	+		
Dimorphococcus lunatus			+		
Schroederia setigera					+
Pediastrum biradiatum			+		
" *duplex*	+	+	+		
" *glanduliferum*			+		
" *simplex*			+		
" *tetras*	+	+	+		

TABLE II—*Continued*

	Mountain	Piedmont	Coastal Plain	Brown Water	Small Pools
Sorastrum americanum			+		
Coelastrum augustae			+		
" *cambricum*	+	+	+	+	
" *chodati*			+		
" *morus*					+
" *proboscideum*			+		
" *reticulatum*			+		
" *scabrum*			+		
" *sphaericum*		+	+		
Chlorella ellipsoidea					+
" *vulgaris*					+
Westella botryoides		+	+		
Treubaria crassispina		+			
" *varia*			+		
Pachycladon umbrinus	+	+	+		
Oocystis borgei		+	+		
" *lacustris*			+		
" *parva*			+		
Nephrocytium agardhianum		+	+		
" *limneticum*		+			
Chodatella longiseta					+
" *subsalsa*					+
Franceia tuberculata					+
Ankistrodesmus convolutus	+	s	s	+	s
" *falcatus*			+		
" *nannoselene*			+		
Closteriopsis longissima	+	s	+	+	
Selenastrum biraianum		+	+		
" *gracile*			+		
" *westii*	+	+	+		
Kirchneriella contorta			+		
" *elongata*				+	
" *lunaris*			+		
" *obesa*		+			
Quadrigula chodati		+			
" *closterioides*	+				
Tetraedron arthrodesmiforme			+		
" *gracile*		+	+		
" *hastatum*		+			
" *heteracanthum*			+		
" *limneticum*		+	+		
" *lobatum*			+		
" *minimum*			+		
" *planctonicum*			+		
" *quadricuspidatum*		+			
" *regulare*				+	
" *trigonum*			+		

TABLE II—*Continued*

	Mountain	Piedmont	Coastal Plain	Brown Water	Small Pools
Scenedesmus abundans	+	+	+		+
" *acuminatus*			+		
" *armatus*			+		
" *bijuga*		+	+		
" *brasiliensis*			+		+
" *denticulatus*			+		
" *dimorphus*	+	s	s	+	s
" *oahuensis*					+
" *obliquus*					+
" *opoliensis*	+	+			
" *parisiensis*					+
" *producto-capitatus*					+
" *quadricauda*	s	s	s	+	s
" *serratus*					+
Tetradesmus wisconsinensis					+
Lauterborniella elegantissima			+		
Crucigenia apiculata			+		
" *fenestrata*			+		
" *quadrata*		+			
" *tetrapedia*	+	+	+		
Tetrastrum glabrum			+		
" *staurogeniaeforme*					+
Tetrallantos legerheimii			+		
Micratinium pusillum		+			
Gonatozygon aculeatum			+		
" *montaenium*			+		
" *pilosum*			+		
Netrium digitus	+	+	+		+
" *interruptum*	+	+	+	+	+
Spirotaenia condensata		+			
Closterium gracile	+	+			
" *peracerosum*			+		
" *setaceum*			+		
Penium margaritaceum	+	+	+		
Pleurotaenium ehrenbergii	+	+	+		
" *minutum*			+		
" *nodosum*			+		
" *trabecula*			+		
" *tridentulum*			+		
Docidium undulatum			+		
Triploceras gracile			+		
" *verticillatum*	+	+	+	+	
Euastrum bidentatum					+
" *elegans*	+	+			
" *humerosum*			+		
" *sinuosum*			+		
Cosmarium botrytis		+			
" *moniliforme*	v	v	+		
" *ornatum*			+		
" *ovale*	+	+			
Cosmocladium saxonicum		+	+		

TABLE II—*Continued*

	Mountain	Piedmont	Coastal Plain	Brown Water	Small Pools
Micrasterias americana	+	+			
" *apiculata*		+	+		
" *arcuata*			+		
" *denticulata*	+	+	+	+	+
" *floridensis*			+		
" *mahabuleshwarensis*			+		
" *muricata*			+		
" *radiata*	v	v	v		+
" *rotata*	+	+	+		+
" *torreyi*			+		
" *truncata*			+		
Xanthidium antilopaeum				+	
Staurastrum americanum		+	+		
" *arctiscon*		+	+		
" *arachne*			+		
" *brachiatum*		v			
" *chaetoceras*			+	+	
" *curvatum*				+	
" *gracile*	v	v			
" *leptocladon*				v	
" *limneticum*	+				
" *margaritaceum*		+			
" *megacanthum*			+		
" *ophiura*			+		
" *paradoxum*			+		
" *quadrispinatum*				+	
" *setigerum*				+	
" *spiculiferum*		+	+		
" *tohopekaligense*			+		
Arthrodesmus convergens		+			
" *incus*				+	
" *ralfsii*			+		
EUGLENOPHYCEAE					
Euglena acus	+	+	+		
" *acutissima*		+	+		
" *caudata*		+			
" *deses*					+
" *ehrenbergii*		+			
" *ozyuris*			+		
" *proxima*					+
" *rubra*					+
" *spirogyra*					+
" *splendens*		+	+		
" *tripteris*		+			
" *viridis*					+
Lepocinclis ovum	+	s	s		
Phacus brevicauda			+		
" *lemmermannii*				+	
" *longicauda*	+	+	+	+	
" *pleuronectes*			+		
" *suecica*			+		
" *triqueter*		+			

TABLE II—*Continued*

	Mountain	Piedmont	Coastal Plain	Brown Water	Small Pools
Trachelomonas abrupta					+
" *acanthostoma*				+	
" *armata*				+	
" *charkowiensis*					+
" *ensifera*		+			
" *euchlora*		+			
" *gibberosa*		+	+		
" *hispida*		+	+		
" *lolliensis*			+		
" *robusta*		+			
" *schauinslandii*		+			
" *superba*			+		
" *volgensis*		+			
" *volvocina*	v	v	v		+
" *smiewikii*			+		
Eutreptia viridis		+			
XANTHOPHYCEAE					
Leuvenia natans					+
Centritractus belanophorus			+		
Botryococcus braunii	+	+	+		+
" *sudeticus*		+	+		
Ophiocytium cochleare					+
CHRYSOPHYCEAE					
Chromulina ovalis		+			
Chrysococcus rufescens					+
Mallomonas acaroides			+		
" *caudata*	+	+	+		
" *fastigiata*		+			
" *producta*					+
" *tonsurata*			+		
Chrysosphaerella longispina		+	+		
Synura petersenii	+		+	+	
" *spinosa*		+			
" *uvella*	v	v	wv	wv	v
Uroglenopsis americana	+	wv	w	+	
Dinobryon bavaricum	+	v	v	+	
" *campanulostipitum*			+		
" *cylindricum*	v	v	wv	wv	
" *divergens*	+	+	+		
" *pediforme*			+		
" *sertularia*		v	wv		
" *sociale*			+		
BACILLARIOPHYCEAE					
Melosira granulata	v	v	v		
" *islandica*					
" *italica*				w	
" *varians*					
Cyclotella meneghiniana		wv			
Stephanodiscus hantzschi				v	
Rhizosolenia eriensis		+	+		
" *longiseta*			+		
Attheya zachariasi		+	+		

TABLE II—*Concluded*

	Mountain	Piedmont	Coastal Plain	Brown Water	Small Pools
Tabellaria binalis			+		
" *flocculosa*	wv	wv	v	v	+
" *fenestrata*	wv	wv	v		+
Fragilaria crotonensis	+	+			
Synedra affinis	+	+	+	+	
" *amphicephala*		+			
" *nana*		+			
" *ulna*	wv	wv(a)*	wv(a)*	+	
Asterionella formosa	v	v	+		
" *gracillima*			+	vs	
Eunotia alpina		+			
" *gracilis*		+			
" *pectinalis*	+	+	+	+	
Navicula spp.	+	+	+	+	+
DINOPHYCEAE					
Gymnodinium fuscum	s	s	+		
" *limneticum*		+	+		
Glenodinium aciculiferum			+		
" *armatum*			+		
" *penardiforme*		+	+		
" *pulvisculus*					+
Peridinium cinctum	s	s	+		
" *limbatum*			+		
" *volzi*			s		
" *westii*			+		
" *wisconsinense*	vs	vs	+		
Ceratium carolinianum			v	v	
" *hirundinella*	v	v	v		
CYANOPHYCEAE					
Chroococcus dispersus			v		
" *delicatissima*					+
" *elachista*			+		
Anacystis cyanea	+	s*	s*		
" *incerta*			+		
Merismopedia tenuissima		+			
Coelosphaerium naegelianum		+	+		
Gomphosphaeria lacustris				+	
Anabaena affinis	+	+	+	+	
" *circinalis*	s	s	+		
" *spiroides*	+	s	+		
Gonyostomum semen	+	+	+		+
Cryptomonas erosa		+			+
" *ovata*	+	+	+		+

Chlorophyceae descends only slowly, but continuously, until early winter. An autumn drop on the *Chlorococcales* is offset by a rise in desmids as cool weather begins.

The drop in numbers of *Ceratium* in July is more than offset by an increase in numbers of summer *Peridinium* and *Glenodinium* species in late summer. Among these are *P. wisconsinense*, *P. cinctum*, and *G. fuscum*.

The same species of *Chrysophyceae* abundant in spring reappear in September and October and reach an autumn peak of 30% to 50% of their spring abundance in November. Their numbers fall by one half during the coldest months.

Species of *Cyanophyceae* are important during the warmest months only. Species of *Anabaena* are the only abundant blue-greens in unfertilized waters. Occasional small and short-period blooms

occur from early June until early September. The maximum number of filaments generally does not exceed 1,500 per cc. *Anabaena circinalis* and *A. spiroides* are commonest and usually exceed all other algae during July and August. Only occasional filaments are seen in collections made from late September to June.

The curve of total numbers rises, from the winter low in late January, steadily and rapidly to the annual peak in May (June in the Mountains). It drops by 20% and levels out in June, July, and August, and then drops more rapidly from September through November until the winter low is reached in late December.

THE COASTAL PLAIN

The Coastal Plain flora is definitely lower in bulk than that of the Piedmont and Mountain areas, but higher in number of species. The *Chrysophyceae* are more abundant than diatoms and the *Chlorophyceae* are relatively more important than in Piedmont and Mountains, and the *Cyanophyceae*, less important. The flora, moreover, can be divided into two types: that of the clear waters, and that of the brown waters.

All groups except the *Cyanophyceae* begin spring growth in February, and March is the month of greatest total abundance. In clear-water ponds and lakes diatoms reach their peak about mid-March and drop in numbers to the summer low by early May. The *Chrysophyceae* continue their steady increase through April and then fall to the summer low during May and early June. The *Chlorophyceae* are more abundant throughout the winter than in the Piedmont. The species are mostly desmids, and are characteristically the large-celled species. They begin a steady increase in numbers in late January. As many as five genera and seven or eight species are common all winter. By May eight genera occur in most ponds and by July ten genera and twenty or more species occur generally. In May and June the *Chlorococcales* increase and contribute to the increasing abundance of *Chlorophyceae* until mid-August. At this time there begins a slow decrease in numbers of *Chlorophyceae* which continues until the winter low is reached in December. There is hardly any discernible autumn pulse in the desmids.

Dinophyceae are less abundant in the Coastal Plain than any other group. A few winter species, among them *Peridinium limbatum*, are fairly common even in late January. *Ceratium carolinianum* becomes common and occasionally abundant in February and March, but practically disappears by April first. In May *Ceratium hirundinella* and summer species of *Peridinium* and *Glenodinium* begin to increase slowly. The peak in numbers is reached in late August when the slow descent to the winter low begins.

Cyanophyceae are less important in both types of Coastal Plain ponds than in other areas. Short period blooms of the same species characteristic of the inland areas may occur at any time during the warmest months. Occasionally large numbers are encountered but the average bloom lasts for one or two weeks only, and 400 to 500 filaments per cc. is the typical maximum. *Chroococcus* and other colonial and single celled blue-greens seem less abundant than reported for acid waters in other areas.

Only the *Chrysophyceae* increase in numbers in autumn. This group begins a slow climb to the cold weather level beginning in September.

BROWN-WATER LAKES AND PONDS

The largest fresh-water areas in the Coastal Plain are the shallow, brown-water lakes; and hundreds of such ponds also occur in peaty areas. Only three classes of algae are ever important in these waters. *Chrysophyceae* are most common, but never really abundant, during the colder months. There is a small spring pulse beginning in late January and February. *Synura uvella* and species of *Dinobryon* and *Mallomonas* are the chief ones. *Synura petersenii* usually follows *S. uvella* although the two sometimes occur together. *Mallomonas* is not as relatively abundant as in clear-water Coastal Plain or inland waters, but *Dinobryon* is relatively important and may persist rather late into summer in scattered ponds in some years.

The *Chlorophyceae* are almost all desmids. Desmids increase in numbers beginning in February to a peak in May. This is followed by a gradual decline until late autumn. Long spined or large celled species of about five genera are the most abundant algae on a year-round basis.

The most distinctive group is the *Bacillariophyceae*. *Synedra* and *Tabellaria* are almost never abundant as they are in other waters. During the cooler months *Melosira*, especially *M. italica*, is most abundant. *Asterionella gracillima* is also widespread but never abundant. There is a drop in numbers of *Melosira* throughout the spring but *Asterionella*, surprisingly, increases in abundance in July and is most abundant in August and September.

Species of *Cyanopnyceae* are never among the dominants and species of *Dinophyceae* are relatively unimportant also.

The curve of total numbers lacks the spring peak characteristic of northern waters and other areas of this state. There is a small rise in March and April produced by the spring growth of desmids. This is followed by a distinct drop in June and a rise to the annual peak about the last of August. This results from the fairly large numbers of desmids plus the unique summer growth of *Asterionella gracillima*.

The Nannoplankton

A detailed study of the nannoplankton has not been made, but centrifuge concentrations have been examined many times from lakes and ponds in all areas of the state, and a few actual counts made. The nannoplankton is also quite varied as to species but does not appear to equal the euplankton in bulk, as has been reported in other areas. The total number of cells or colonies is frequently somewhat greater than that of the euplankton but not markedly so.

In the Piedmont *Cyclotella meneghiniana* is sporadic during cooler seasons and occasionally abundant. *Cryptomonas* species are common in cool weather also, as well as several small-celled species of *Chrysophyceae*. Several *Scenedesmus* species are perennial and may show small pulses at almost any time. *Trachelomonas volvocina* and other small species are also perennial. During warm weather many other small euglenoids are common along with many flagellated *Chlorophyceae*. *Chlamydomonas* and *Coccomonas* are frequently abundant. Various small-celled species of *Chlorococcales* such as *Tetraedron minimum*, *Chlorella sp.* and *Crucigenia sp.* are widespread. Small species of *Cosmarium* are occasionally abundant in spring.

In the Mountains, under similar conditions, the nannoplankton is apparently identical to that of the Piedmont.

In clear-water Coastal Plain waters the nannoplankton consists almost entirely of small-celled species of *Chlorococcales* and desmids. Apparently many are the same species found in the Piedmont and Mountains, but a few such as *Crucigenia apiculata*, *Kirchneriella contorta*, and *Lauterborniella elegantissima* are distinctive of the Coastal Plain.

In the brown waters the nannoplankton seems very sparse. A few species of *Cyanophyceae* such as *Chroococcus dispersus* are most common.

The Farm Pond

A comparative study of the plankton of some fifty fertilized and unfertilized farm ponds has been made over a period of five months during the summer and autumn of two years, and scattered collections at other seasons have been examined. The fertilized ponds show a definite trend toward eutrophication, without a change in dominant genera, however. The only exception is *Anacystis* (*Microcystis*). *Anacystis cyanea* is relatively rare in unfertilized waters, although widespread during the warm months. The only blooms of *Anacystis* ever observed in the state occurred in heavily fertilized farm ponds. The same species of *Anabaena* found in unfertilized ponds are several times as abundant during July, August, and September in fertilized ponds. Species of *Chlorococcales* are much more abundant also in fertilized ponds in early summer. *Synedra* appears to be the most abundant diatom genus. It becomes quite abundant in fertilized ponds in late autumn and apparently is relatively abundant all winter. It seems apparent that *Chrysophyceae* and desmids are relatively much less abundant than in unfertilized ponds. The unfertilized small pond, where little affected by agricultural practices, has the same algal flora characteristic of larger ponds in the same area.

Discussion

The records at hand while incomplete as to actual numbers of organisms, are accurate enough to indicate relative abundance and dominance, and voluminous enough over a period of many years to denote the average seasonal relations. These data justify the following conclusions:

1. The flora in each of the three regions is of the Caledonian type.[2]
2. Whether it is direct or indirect, there is a correlation with two factors; hydrogen ion concentration, and water temperature.
3. There is a closer correlation between the North Carolina floras and those of other regions similar in geologic conditions than with those of regions similar in climate.

Attempts to correlate the abundance of classes, or even genera, of organisms with any specific habitat factors seem to indicate that the conclusions of Hutchinson, Pennak, and Ruttner (Frey and Fry translation 1953) et al. are justified. They agree that the interaction of many factors such as limiting nutrients, ratios of ions, trace elements

[2] See the phytoplankton, page 146.

and dissolved organic compounds determine the presence in large numbers of any one species or group. These conditions in turn are produced by the whole complex of chemical, physical, and climatic conditions. Geologic and climatic conditions limit and control the activities of the non-green reducers on the one hand and the photosynthetic producers on the other (Odum 1953). These complexes produce the low nutrient, low pH conditions under which the Caledonian ("oligotrophic") floras exist. Under such conditions where a large number of species can survive, any slight shift in temperature, pH, or nutrient level can immediately allow specific organisms to become relatively abundant for a short period of time. This explains the short period "blooming" of *Anabaena* at almost any time during the warm months, and the variation in abundance from year to year and pond to pond of such genera as *Dinobryon* and *Asterionella*.

In the Piedmont, where varying run-off and the effect of agricultural practices is most pronounced, one finds the greatest variation in flora from pond to pond, season to season, and year to year. The nutrient level here is higher and more varied. In the clear-water Coastal Plain pond the nutrient level is lower and less varied. Here, therefore, the Caledonian type is more pronounced. In the brown-water pond, pH and nutrient levels are lowest, and habitat conditions, except temperature, vary the least. The flora here changes least seasonally because nutrient levels, etc. change little. It is not unusual to find four or more species sharing dominance in a pond of this type.

As would be expected, the type of flora corresponds most closely to that described by Schumacher (1956) in southwest Georgia. There is also a greater similarity to the floras of acid, soft-water areas even in the sub-arctic than to those of Reel-foot Lake, Tennessee (Eddy, 1930) in the same latitude, or to those of the north Texas reservoirs investigated by Harris and Silvey (1940). Diatoms are apparently much less important than in the northern U. S. and Canada or in Colorado and the far west. (Daily, 1938; Damann, 1938; Chandler, 1945; Verdouin, 1951; Pennak, 1949; Schumacher, 1956, et al.). The geologic factors determining water quality seem definitely more important than climate.

One additional observation is worth mentioning. During the past 20 years there has been considerable attention directed toward the possibility that phosphorus may be an important factor affecting the abundance of plankton algae. Pearsall (1922), Rhode (1948), and Hutchinson (1944) have discussed this problem. Recently Abbott (1957) has suggested the possibility that plankton organisms may be able to liberate and use phosphorus compounds adsorbed on clay micelles in water. This idea is being investigated at this time by the writer and an associate.

SUMMARY

The data obtained were largely from net plankton collections made in all types of still waters in the three physiographic provinces of the state over a period of more than ten years. The plankton is Caledonian but three types of floras are recognized.

The Piedmont and Mountain (1) is the most varied with *Chrysophyceae* and *Bacillariophyceae* dominant in winter and spring and *Chlorophyceae*, *Dinophyceae*, and *Cyanophyceae* dominant in summer and autumn. The Coastal Plain flora (2) is lower in bulk and has *Chrysophyceae*, *Bacillariophyceae*, and *Chlorophyceae* dominant in winter and early spring with the *Chlorophyceae* dominant in late spring, summer, and autumn. The brown-water Coastal Plain flora (3) is still lower in bulk, with the *Chlorophyceae* (desmids) dominant most of the year. A unique feature of this flora is the relative abundance of the diatom *Asterionella gracillima* in late summer.

Nannoplankton is quite varied as to species but apparently does not equal the euplankton in bulk.

The heavily fertilized farm pond shows a trend toward eutrophication without a change in dominant genera except in summer. *Anacystis* (*Microcystis*) *cyanea* frequently forms summer blooms in fertilized ponds.

There seems to be a correlation between type of flora and hydrogen ion concentration, and with temperature.

There is a closer correlation between the North Carolina floras and those of other regions similar in geologic conditions than with those of similar climate.

LITERATURE CITED

ABBOTT, W. 1957. An unusual phosphorus source for plankton algae. Ecology **38:** 152.

ALBRECHT, W. A. 1940. Calcium-potassium-phosphorus relation as a possible factor in ecological array of plants. Jour. Amer. Soc. Agron. **32:** 411–418.

BAILEY, J. W. 1851. Microscopical observations

made in South Carolina, Georgia, and Florida. Smithson. Contrib. to Knowl. **2:** 1–48.

BIRGE, E. A. AND C. JUDAY. 1922. The inland lakes of Wisconsin. The Plankton I. Its quantity and chemical composition. Bull. Wis. Geol. and Nat. Hist. Surv. **22:** 1–222.

BOURRELLY, P. 1957. Algues d'eau douce Soudan Francais, region du Macina (A.U.F.). Bull. de l'Ifan. **19:** 1048–1102.

BROWN, H. J. 1930. The desmids of the southeastern Coastal Plain region of the United States. Trans. Amer. Micro. Soc. **49:** 86–104.

CHANDLER, DAVID C. AND OWEN B. WEEKS. 1945. Limnological studies of Western Lake Erie. V. relation of limnological and meterological conditions to the production of phytoplankton in 1942. Ecol. Monographs **15:** 435–456.

COCKE, E. C. 1949. The Myxophyceae of North Carolina. Jour. Elisha Mitch. Sci. Soc. **65:** 71–89.

COKER, R. E. 1954. Streams, lakes, ponds. Univ. North Carolina Press. 1–327. Chapel Hill.

CROASDALE, H. T. 1957. Fresh-water algae of Alaska. I. Some desmids from the interior, part 3. Trans. Amer. Mic. Soc. **76:** 116–157.

DAILY, W. A. 1938. A quantitative study of the phytoplankton of Lake Michigan collected in the vicinity of Evanston, Illinois. Butler Univ. Bot. Stud. **4:** 65–83.

DAMANN, K. E. 1938. A quantitative study of the phytoplankton of Lake Michigan at Evanston, Illinois. Butler Univ. Bot. Std. **5:** 27–44.

DAMANN, K. E. 1945. Plankton studies of Lake Michigan. I. Seventeen years of plankton data collected at Chicago, Illinois. Am. Midl. Nat. **34:** 769–796.

DROUET, F. AND W. A. DAILY. 1956. Revision of the coccoid Myxophyceae. Butler Univ. Bot. Stud. **12:** 1–218.

EDDY, S. 1930. The plankton of Reel-foot Lake, Tennessee. Trans. Amer. Micro. Soc. **49:** 246–251.

FOREST, H. S. 1954. Handbook of algae with special reference to Tennessee and the southeastern states. Univ. Tenn. Press pp. 1–467.

GRONBLAD, R., G. A. PROWSE, AND A. M. SCOTT. 1958. Sudanese desmids. Acta. Bot. Fenn. **58:** 1–82.

HARRIS, B. B. AND J. K. G. SILVEY. 1940. Limnological investigation on Texas reservoir lakes. Ecol. Monogr. **10:** 111–143.

HASLER, A. D. 1948. Fertilization for increasing productivity of natural inland waters. Trans. 13th. N. Amer. Wildlife Management Inst. Mar. 1948.

———. 1947. Eutrophication of lakes by domestic drainage. Ecology **28:** 383–395.

HIRANO, M. 1956 Notes on some phytoplankton from Lake Akan. Acta Phytotax. Geobot. **16:** 101–105.

HOHN, M. H. 1951. A study of the diatoms (Bacillarieae) in Western New York State. Cornell Univ. Agr. Exp. Stn. Memoir **308:** 1039.

HUGHES, E. O. 1952. Phytoplankton of some maritime lakes. Canad. Field Nat. **66:** 167–170.

HUTCHINSON, G. E. 1944. Limnological studies in Connecticut VII. Examination of the supposed relationship between phytoplankton periodicity and chemical changes in lake waters. Ecology **25:** 3–26.

JUDAY, C. 1943. The summer standing crop of plants and animals in four Wisconsin lakes. Trans. Wis. Acad. Sci. Art. Let. **34:** 103–135.

KUEHNE, P. E. 1941. The phytoplankton of southern and central Saskatchewan. Canadian Jour. Res. **19:** 313–322.

LACKEY, J. B. AND C. N. SAWYER. 1945. Plankton productivity of certain southeastern Wisconsin lakes as related to fertilization. Sewage Works. Jour. **17:** 573–585.

LUND, J. W. G. 1947. Four new green algae. Revenue Algologique ns. **3:** 26–44.

MADSEN, G. AND C. S. NIELSEN. 1948. Check list of the algae of northern Florida II. Florida State Univ. Stud. **1:** 1–21.

NEWCOMBE, C. L. AND J. V. SLATER. 1950. Environmental factors of Sodon Lake—a dichothermic lake in southeastern Michigan. Ecol. Monogr. **20:** 207–227.

PASCHER, A. 1914–30. Die Süsswasserflora Deutschlands, Osterreich u.d. Schweiz. Jena.

PENNACK, R. W. 1949. Annual limnological cycles in some Colorado reservoir lakes. Ecol. Monogr. **19:** 233–267.

PHILLIPS, R. C. AND L. A. WHITFORD. 1958. Additions to the fresh-water algae in Northern Carolina II. Castanea **23:** 25–30.

PHILSON, P. J. 1939. Fresh-water algae of North and South Carolina. Part I. Cyanophyceae. Elisha Mitch. Sci. Soc. **55:** 83–116.

PLATT, R. B. AND C. S. SHOUP. 1950. The use of a thermistor in a study of summer temperature conditions of Mountain Lake, Virginia. Ecology **31:** 485–488.

PRESCOTT, G. W. 1939. Some relationships of phytoplankton to limnology and aquatic biology. A.A.A.S. Publication No. **10:** 65–78.

PRESCOTT, G. W. 1951. Algae of the western Great Lakes area. Cranbrook Inst. Sci. Bull. **31:** 1–946. Bloomfield Hills, Mich.

RAY, C. E. JR. AND E. E. RANDOLPH. 1928. Preliminary report on the chemical quality of the

surface water of North Carolina, etc. Econ. Paper No. 61, N. C. Dept. Conserv. and Devel.

RAYMOND, M. R. 1937. A limnological study of a concretion-forming marl lake. Trans. Amer. Micro. Soc. **56:** 405–430.

RODHE, W. 1948. Environmental requirements of fresh-water plankton algae. Symb. Bot. Upsal. **10:** 1–149.

SCHUMACHER, G. J. A qualitative and quantitative study of the plankton algae in southwestern Georgia. Amer. Midl. Nat. **56:** 88–115.

SCOTT, A. M. AND R. GRÖNBLAD. 1957. New and interesting desmids from the southeastern United States. Acta. Soc. Sci. Fenn. n.s. B. **2:** 1–62.

SERFLING, R. E. 1949. Quantitative estimation of plankton from small samples of Sedgewick-Rafter-cellmounts of concentrate samples. Trans. Amer. Micro. Soc. **68:** 185–199.

SILVA, H. 1948. A review of phycological research in southeastern United States. Castanea **13:** 133–141.

SKUJA, A. 1948. Taxonimie des Phytoplanktons einiger Seen in Uppland, Schweden. Symbol. Bot. Upsal. **9:** 1–399.

———. 1949. Zur Susswasseralgenflora Burmas. Nova Acta Reg. Soc. Sci. Upsal. Ser. IV, **14:** 1–188.

SMITH, G. M. 1920. Phytoplankton of the inland lakes of Wisconsin. Parts I, II. Wis. Geol. and Nat. Hist. Surv. Bul. 57.

———. 1924. Ecology of the plankton algae in the Palisdades Interstate Park, including the relation of control methods to fish culture. Roosevelt Wild Life Bull. **2:** 94–195.

SMITH, G. M. 1950. The fresh-water algae of the United States. 2nd. ed. 1–719. New York.

SMITH, G. M., Ed. 1951. Manual of Phycology. Chronica Botanica Co. Waltham, Mass.

THOMPSON, R. H. 1947. Fresh-water dinoflagellates of Maryland. Chesapeake Biol. Lab. Pub. No. 67. 1–28.

THUNMARK,. S 1945. Zur Sozologia des Süsswasserplanktons. Folia. Limno. Scand. No. **3:** 1–66.

TIFFANY, L. H. 1943. The plankton algae of the west end of Lake Erie. Contrib. Franz. Stone. Lab. No. **6:** 1–112.

TRANSEAU, E. N. 1916. The periodicity of fresh-water algae. Amer. Jour. Bot. **3:** 121–133.

VERDUIN, J. 1951. Comparison of spring diatom crops of western Lake Erie in 1949 and 1950. Ecology **32**(4): 662–668.

———. 1951. Photosynthesis and growth rates of two diatom communities in western Lake Erie. Ecology **33**(2): 163–168.

VINYARD, W. C. 1957. Algae of the Glacier National Park region, Montana. Proc. Mont. Acad. Sci. **17:** 49–53.

WADE, W. E. 1949. Some notes on the algal ecology of a Michigan lake. Hydrobiologica **2:** 109–117.

WALLEN, I. E. 1949. The plankton population of a small fertile pond in central Oklahoma. Trans. Amer. Micro. Soc. **68:** 200–205.

WELCH, P. S. 1938. A limnological study of a bog lake which never developed a marginal mat. Trans. Amer. Micro. Soc. **57:** 344–357.

———. 1938b. A limnological study of a retrograding bog lake. Ecology **19**(3): 435–453.

WELCH, P. S. 1952. Limnology. 2nd. ed. 1–538. New York.

WHITFORD, L. A. 1936. New and little known algae from North Carolina. Jour. Elisha Mitch. Sci. Soc. **52:** 93–98.

———. 1943. The fresh-water algae of North Carolina. Jour. Elisha. Mitch. Sci. Soc. **59:** 131–170.

WHITFORD, L. A. 1950. Some fresh-water algae from Mississippi. Castanea **15:** 117–123.

———. 1956. Additions to the fresh-water algae in North Carolina. I. Trans. Amer. Micro. Soc. **75:** 196–203.

———. 1956b. The communities of algae in the springs and spring streams of Florida. Ecology **37:** 433–442.

WURTZ, A. 1948. Assai d'hydrobiologie comparee appliquee aux etangs. I. Relations entre le phytoplankton et les methodes de culture des etangs. Ann. Stn. Centr. d'Hydrobiol appl. **2:** 93–127.

SOME ADDITIONS TO THE FRESH-WATER ALGAL FLORA OF NORTH CAROLINA: ALGAE OCCURRING WITH *SPHAGNUM*[1]

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The various species of fresh-water algae which occur in North Carolina have received intermittent attention in the literature for almost a century, and during this period the number of species known to occur in the state has grown continually. One particular type of algal habitat, however, the sphagnum bog community, has still not been adequately studied. Relatively high acidity of the water is characteristic of the boggy places inhabited by species of *Sphagnum*, and this is probably important both in preventing the growth of many algal species which might otherwise occur and in permitting growth of certain species which are unable to survive in less acid environments. This paper is a report of a study of the algae occurring in and on sphagnum plants of bog communities.

Among the general publications on the fresh-water algae of North Carolina, the most comprehensive is that of Whitford (1943), which presents a systematic, annotated list of all published records of fresh-water algae occurring in the state together with the records from that writer's own survey. Of all the species of algae now known to occur, almost fifty per cent were first reported in that paper. The same paper also includes a brief resumé of all earlier literature on the subject. Since 1943, additional species of algae have been reported in several papers. Cocke's publication (1949) on the blue-green algae of North Carolina included records of several species previously unknown in the state. Silva (1949) reported several species new for the southeastern United States, some of these species being found in North Carolina. The number of species known to occur has been further increased by Whitford (1956) and by Phillips and Whitford (1958).

Of the various algae reported in this present study, certain species were rarely or never found except within the leaves of *Sphagnum*, and for this reason these leaves should be briefly described. *Sphagnum* leaves are only one layer of cells thick throughout. The leaves are composed of two types of cells: (1) small, more or less cylindrical, chloroplast-containing cells which are joined end on end forming a reticulum; and (2), much larger cells (known as hyaline cells) devoid of any cellular content at maturity and therefore transparent, which occur between the chlorophyllose cells and more or less enclose them by their bulging walls. In most species of *Sphagnum* these hyaline cells are open to the outside by means of variable-sized pores in the cell walls. During wet seasons when the sphagnum plants are submerged, water displaces the air in the hyaline cells of the leaves. The pores make possible the entry of algae into the empty cells; and the transparency of these cells both permits the normal process of photosynthesis in the algae and makes possible the microscopic examination of these algae as they exist within this limited environment.

Methods

Although typical, extensive sphagnum bogs do not occur in North Carolina, small bog communities are common and four of these near Durham (Durham County) were selected for thorough study. Collections of sphagnum were regularly made in each of these communities over a period of eleven months from February, 1951 until January, 1952. Collections included principally those portions of the moss at and above the water level. During the period of study the water level rarely was high enough to completely submerge the sphagnum plants. In addition to these principal collections, other groups of collections brought in from the following areas were studied: three from other locations in Durham County, two from Granville County, and one each from Franklin County and Carteret County. Five species of *Sphagnum*, *S. compactum* DC., *S. cuspi-*

[1] Based on part of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts in the Graduate School of Arts and Sciences, Duke University.

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datum Ehrh., *S. imbricatum* Kornsch., *S. palustre* L., and *S. subsecundum* Nees., occur in one or more of the areas represented.

Each collection was brought back to the laboratory where it was examined for the presence of algae. In several instances throughout the year specimens of sphagnum which contained few or no algae in the vegetative condition did contain numerous algal spores in the hyaline cells of the leaves. In each of these instances, a few of the spore-containing leaves from a specimen were used to inoculate a medium of Knop's solution and the algae were subsequently identified from the culture obtained.

RESULTS

With few exceptions, the algae found were of sporadic occurrence in sphagnum communities and were rarely found in large numbers. Some species were most commonly found inside the hyaline cells of sphagnum leaves. Other species were found attached either on the surface of the plant or within the hyaline cells of the leaves. Still other species occurred clinging to or growing over the surface of the moss. Usually greater numbers of species of algae and also greater numbers of individuals occurred with those species of *Sphagnum* having larger hyaline cells in the leaves (*S. imbricatum*, *S. palustre*, *S. subsecundum*) than occurred with those species having smaller hyaline cells (*S. cuspidatum*, *S. compactum*).

In the following list of algae, brief notes regarding frequency of occurrence, seasons collected, etc. are included with each species. Newly reported here for North Carolina are 3 genera, 11 species, and 1 variety; and 1 species is newly reported for the United States. Species of algae which were present but which have earlier been reported to occur in North Carolina are not included in this paper. Except where otherwise noted, the algae listed here were collected in Durham County. The systematic arrangement used is that of Smith (1950).

Chlorophyceae

VOLVOCALES.—*Chlamydomonas regularis* Korschikoff. Frequently present. All seasons. Individuals were found swimming both inside the hyaline cells of leaves and in the water outside the leaves. Most commonly found with either *Sphagnum palustre* or *S. subsecundum*. Species newly reported for North Carolina.

ULOTRICHALES.—*Hormidium subtile* (Kutz.) Herring. Rare. Autumn. Found in two cultures inoculated with leaves of *Sphagnum subsecundum* from one collection. Genus and species newly reported for North Carolina.

CHLOROCOCCALES.—*Characium obtusum* A. Braun. Rare. Autumn. Found attached to outside of leaves of *Sphagnum cuspidatum*. Species newly reported for North Carolina.

ZYGNEMATALES.—*Mesotaenium Greyii* var. *breve* W. West. Rare. Winter. Found in large numbers with a single collection of *Sphagnum cuspidatum* from a low bank. It is of interest that the original description of this variety is based on specimens found growing on a wet mossy bank. Variety newly reported for North Carolina.

Cosmarium circulare Reinsch. Winter. Found with a single collection of *Sphagnum subsecundum* from "flat rock" (Franklin County). Species newly reported for North Carolina.

Euglenophyceae

EUGLENALES.—*Euglena Klebsii* Mainx. Of all the species of algae found in the bog communities studied, this species was most frequently present, occurring in 26 per cent of all collections. All seasons. Encysted and free swimming forms found both inside the hyaline cells and in the water around the moss. Species newly reported for North Carolina.

Euglena velata Klebs. Rare. Autumn. Found with a single collection of *Sphagnum palustre* from Granville County. Species newly reported for North Carolina.

Xanthophyceae

HETEROCOCCALES.—*Botrydiopsis minor* Schmidleem. Rare. Autumn. Found in two cultures inoculated with leaves of *Sphagnum subsecundum* from two localities. Genus newly reported for North Carolina; species newly reported for the United States.

Characiopsis pyriformis Borzi. Frequent in occurrence and occasionally present in large numbers. All seasons. Almost invariably found attached to the inner walls of hyaline cells of the leaves. Although this alga was found associated with all species of *Sphagnum* occurring here, it was most commonly found with *S. plaustre* and *S. subsecundum*. The only species reported in this paper which was found in all communities studied. Genus and species newly reported for North Carolina.

Characiopsis sublinearis Pascher. Rare. Autumn. Found attached within hyaline leaf cells of *Sphagnum subsecundum*. Species newly reported for North Carolina.

Characiopsis tuba Lemmermann. Rare. Winter. Found within hyaline leaf cells of *Sphagnum palustre*. Species newly reported for North Carolina.

Myxophyceae

OSCILLATORIALES.—*Lyngbya cliarensis* W. West. Rare. Summer, winter. Found with *Sphagnum compactum* and *S. subsecundum*. Species newly reported for North Carolina.

ACKNOWLEDGMENTS

It is a pleasure for me to express my sincere appreciation to Dr. H. L. Blomquist, to whom I am particularly indebted for his generous help and advice concerning this work. I also wish to thank Dr. Francis Drouet of the Chicago Natural History Museum and Dr. H. C. Bold of the University of Texas for checking my identification of certain species.

LITERATURE CITED

COCKE, E. C. 1949. The Myxophyceae of North Carolina. Jour. Elisha Mitchell Sci. Soc. **65**: 71–89.

PHILLIPS, R. C., AND L. A. WHITFORD. 1958. Additions to the fresh-water algae in North Carolina II. Castanea **23**: 25–30.

SILVA, HERMAN. 1949. Additions to the algae of the southeastern United States. Jour. Elisha Mitchell Sci. Soc. **65**: 90–109.

SMITH, G. M. 1950. Fresh-Water Algae of the United States. New York, McGraw-Hill.

WHITFORD, L. A. 1943. The fresh-water algae of North Carolina. Jour. Elisha Mitchell Sci. Soc. **59**: 131–170.

WHITFORD, L. A. 1956. Additions to the fresh-water algae in North Carolina I. Trans. Amer. Micros. Soc. **75**: 196–203.

SPORE DISCHARGE IN *TAPHRINA*

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The ascomycetous genus *Taphrina*, according to a recent monograph by Mix (1949), includes 98 valid species of fungi. For the most part its suscepts are certain species among the Amentiferaceae and Rosaceae and a few species of ferns.

The genus *Taphrina* was established by Fries in Systema Mycologicum in 1832, and, as indicated by the extensive bibliography in this monograph by Mix (1949), has been a favorite one for study by those interested in its taxonomy, phylogeny, cytology, and developmental morphology. But with the exception of Yarwood (1941), who found that spore discharge in *Taphrina deformans* (Fkl.) Tul. is rhythmic, apparently no one has given consideration to spore liberation of any of its species. The present observations add to the general fund of knowledge of spore discharge of two other members of *Taphrina*, namely *T. caerulescens* (Desm.) Tul., the cause of leaf-curl of oaks, and *T. communis* (Sadeb.) Giesenbag. (*Exoascus mirabilis* Atk.), the cause of bud galls on wild plum, *Prunus angustifolia* Marsh.

Observations.—If lesions on oak leaves are sectioned free-hand for microscopic examination it may be noted that, at any given time, the asci vary greatly in size and shape. All asci are seen to be *thick-walled*. Those having lateral walls that are parallel and apices that are truncate contain relatively few blastospores, measuring 2.0–3.0 × 1.0–1.5 μ. Those that are saccate and apically rounded are gorged with bacilliform blastospores, and their volume is two or more times greater than that of the former kind. It would appear therefore that variation in shape and size is related to ascal maturity, assuming that spore discharge occurs when maturity is reached.

Taphrina caerulescens yields no evidence of diurnal rhythm in maturation of asci and in discharge of spores such as was shown in *T. deformans* by Yarwood (1941). The evidence for such lack arises from tests in which diseased leaves were placed on moist filter paper in the tops of inverted poured agar plates. At various times throughout the day and night, after exposure of an hour or more, the plates were removed and replaced by others. Then by direct examination of the exposed agar plates it was noted that droplets, consisting of cytoplasm and embedded blastospores, were adhering to the agar surface in all plates. The entire ascus content is liberated as a unit, following apical rupture of the ascus. Rupture is the climax of a gradual increase in osmotic pressure within the maturing ascus. When maturity is attained, the distended apical wall breaks and the ascus content is propelled like a missile or projectile, lodging on the agar surface.

Similarly, it was found by making series of exposures of inverted agar plates, that *T. communis* also lacks diurnal periodicity in maturation of asci. Moreover, its asci are *thin-walled* and its ascospores are expelled in groups of eight. Mix (1949) states that the ascospores of this species frequently bud while still within the ascus but in the plum gall material such proliferation was not noted. When pieces of hypertrophied buds were placed in contact with the surface of agar plates and allowed to remain for several hours before removal, the 8-spored projectiles were found to have been discharged so that they thickly covered a circular area 2.0–2.5 cm. in diameter. Mature asci of this species measure approximately 13 μ but each adhering projectile has a diameter of approximately 20 μ, hence is flattened by impact.

Discussion.—The genus *Taphrina* was early divided into two subgenera, *Eu-Taphrina*, having asci filled with bacillar cells, and *Ascomyces*, lacking asci filled with bacillar cells i.e. each ascus being 8-spored. *Taphrina caerulescens* therefore, belongs in the former subgenus and *T. communis* in the latter. However, division into these two subgenera is generally held to be untenable, since the ascospores in a given species may or may not bud within the ascus. The causal factors that control discharge as related to number of spores remain unknown. In my opinion the thickess and correlated extensibility of the ascus wall are among these factors. Each ascus in *Taphrina* stands free, hence is not subjected to compression from nearby asci. Under such a condition ascus distention is not impeded by neighboring asci and

ascal dimensions may be expected to vary with degree of maturity. Mix (1949) did not assign a reason for ascus variability but did point out that size and shape of asci are not good taxonomic characters.

A knowledge of the force exerted to propel the ascus content (missile) of *Taphrina* should have more than passing interest. *Taphrina communis* was found to be capable of hurling its missile a maximum distance of approximately 12,000 μ. To gain an idea of the force involved one must make certain assumptions to use in calculations.[1] Disregarding air resistance one may assume that the missile is a sphere 15 μ in diameter, with a specific gravity of 1.0, the ascus gun being set at an angle of 45°, and that the force (F) was applied for 10^{-5} seconds.

Based on these assumptions the mass (m) of the projectile becomes 1.714×10^{-9} gm.; the initial velocity (V) becomes 0.313 cm/sec; the momentum (M), 5.5×10^{-9} gm/cm/sec. and the force (F), 5.5×10^{-3} dynes.

[1] Thanks are hereby extended to Dr. W. M. Nielsen for making these calculations.

These values, being based on assumptions, may be found when the phenomenon of discharge is tested experimentally, not to be true. Be that as it may, the force exerted must be relatively large and takes on meaning when it is appreciated that the missile of *T. communis* is hurled a distance of 800 times that of the missile diameter.

SUMMARY

The multispored ascus content of *Taphrina caerulescens* and the 8-spored content of *T. communis*, are discharged as units. The latter species propels the ascus content laterally a maximum distance of approximately 1.2 cm. Variation in size and shape of asci within a given species of *Taphrina* appears to be related to degree of ascal maturity.

LITERATURE CITED

MIX, A. J. 1949. A monograph of the genus *Taphrina*. Univ. Kansas Sci. Bull. **33**: 1–167.

INGOLD, C. T. 1939. Spore discharge in land plants. 178 pp. Clarendon Press: Oxford.

YARWOOD, C. E. 1941. Diurnal cycle of ascus maturation of *Taphrina deformans*. Amer. Jour. Bot. **28**: 355–357.

THE CONIDIAL STAGE OF *LAMPROSPORA TRACHYCARPA* (CURREY) SEAVER

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Lamprospora trachycarpa is an operculate cupfungus of wide distribution throughout the United States and Europe. It belongs in the family Pezizaceae, tribe Sphaerosporae, and was first described from England by Currey (1864), who named it *Peziza trachycarpa*, referring to its verrucose spore wall.

The genus *Lamprospora* is characterized by possession of naked, fleshy, discoid apothecia, and spherical, rough-walled or smooth-walled ascospores. According to Seaver (1942), there are 30 species included within the genus, nearly all of which are soil-inhabiting. Members of this group have been given various generic names such as *Ascobolus*, *Aleuria*, *Barlea*, *Crouania*, *Detonia*, *Humaria*, *Plicaria*, and *Plicariella*.

So far as the writer has been able to determine from perusal of mycological literature, none of the species of Lamprospora, as delimited by Seaver (1942), is known to possess a conidial stage, and such occurrence seems to be rare among operculate Discomycetes. In fact, Seaver (l.c., vide p. 21) states "While asexual spores have been reported for a few operculate cupfungi, such as *Peziza vesiculosa* Bull. and *Peziza repanda* Pers., on the whole, this type of reproduction is conspicuous by its absence in many species of this group, or, at least, has not been observed".

Apparently Brefeld (1891) first recorded that both *Peziza vesiculosa* and *P. repanda* possess conidia. He did not identify them, but his illustrations indicate that each is of different generic type. Subsequently Dodge (1937) found that *Peziza pustulata* (Hedw.) Pers. has a conidial stage of the Oedocephalum type resembling that of *P. repanda*, as illustrated by Brefeld. More recently Schneider (1954) isolated in cultures derived from ascospores of *Plicaria fulva* a conidial stage which she did not identify but stated that it is closely related to Rhinotrichum and Botrytis. As suggested by Wolf (1957), this conidial stage of *P. fulva* resembles closely the form genus Microtypha, but its proper classification can be known only after further study.

The present observations establish that *Lamprospora trachycarpa* has a conidial stage and indicate the need for attempts to find whether operculate discomycetes generally have conidia.

Observations.—During the fall of 1957 this fungus was abundant in the greenhouses of Duke University. The apothecia occurred singly or in clusters of as many as six, adhering closely to each other and to the soil. They are sessile to substipitate and vary in diameter from 0.5 cm. to 3 cm. At first they are yellowish brown, becoming brownish black with age or with desiccation. When the apothecia stand singly, they are shallow cup-shaped with incurved margins, but when clustered their shape is irregular and the hymenial surface may be plane or convoluted, occasionally being partly elevated above the margin of the disks. The medulla is composed of loosely arranged cells that vary enormously in size (Fig. 5) The spherical ascospores are arranged uniseriately in the upper half of the cylindric asci (Fig. 1). They remain smooth-walled until a few days prior to maturity when characteristic, short, flat, irregularly-oriented, verrucose ridges are formed at their surface (Fig. 3). The asci range in size from 250–300 × 16–19 μ and are provided with an apical, centrally-located operculum or lid (Fig. 2). The ascospores have a diameter of 15–18 μ. The paraphyses are unbranched, septate, extend slightly beyond the asci, and generally the tips are enlarged.

To isolate this fungus in culture apothecia were placed on moist filter paper in the tops of inverted poured agar Petri plates. Under such conditions the ascospores together with a droplet of fluid, the protoplasmic content of the ascus, are ejected violently. They adhere to the surface of the agar, usually in groups of 8, but they may become separated during flight. Nutrient agar, potato dextrose agar, or agar enriched with soil extract served for germination of the ascospores (Fig. 4) and subsequent mycelial growth. But only a very small proportion germinated in these media within a period of 48–72 hours. Isolates on each medium, when transferred to slants, produced

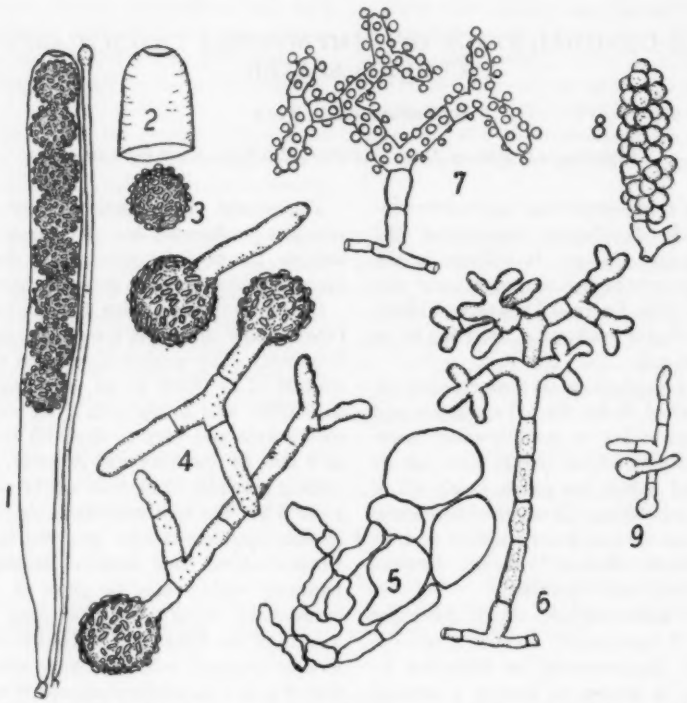

FIG. 1. Ascus and paraphysis of *Lamprospora trachycarpa*. FIG. 2. Ascus tip with operculum, twice the diameter of fig. 1. FIG. 3. Ascospore, enlarged corresponding to fig. 2. FIG. 4. Germinating ascospores swollen from the size of ascospore, shown in fig. 3. FIG. 5. Medullar tissue of apothecium. Cells loosely arranged and variable in size. FIG. 6. Young conidiophore. FIG. 7. Depauperate conidiophore. An early stage of conidial formation. FIG. 8. Single terminal part of *Rhinotrichum trachycarpum*, a mature conidiophore of magnification the same as that in Fig. 1. FIG. 9. Germinating conidia.

conidia sparingly, requiring a period of about 2 weeks for conidial development. Sterilized bean pods or sterilized soil rich in organic matter, however, provided for copious production of conidia.

On potato dextrose agar the mycelium is white and floccose at first, but gradually densely interwoven, yellowish-brown mats or encrustations are formed, especially in Petri plate cultures. The conidiophores originate as erect, septate, lateral branches having a diameter somewhat in excess of that of the vegetative hyphae (Fig. 6). They soon become dendritic by repeated dichotomous or trichotomous branching, standing either singly or in groups. The terminal portions of the branches bear numerous, sterigmata-like or denticulate protrusions (Fig. 7). The apices of these sterigmata become spherical and are soon delimited to become conidia. A single conidium is formed on each sterigma. At length the globular conidia copiously clothe the ends of the branches, obscuring the conidiophores (Fig. 8). The conidia range in size from 4.6 to 7.2 μ and their wall is fuscous.

This organism when grown on certain media varies in appearance to a greater extent than does any fungus that the writer has encountered. On malt extract agar, for example, the mycelium is very copious and white at first, becoming tawny with age. On yeast extract agar the mycelium is fuscous, sparse, and adpressed. When grown on tryptophane agar, mycelial growth is exceedingly sparse but when the medium contains both tryptophane and sucrose the growth is copious, white at first, becoming tawny later, and the anastomosed hyphae that penetrate between the agar and the test tube wall are coal black. On these media conidia developed in abundance only

FIG. 10. Conidial production on sterilized soil.

on agar containing tryptophane or both yeast extract and sucrose.

DISCUSSION.—To date only meager attention has been given to the isolation and cultivation on artificial media of operculate cup-fungi. Students of this group of organisms have devoted themselves largely to matters of their geographic distribution, gross morphology, taxonomy, and nomenclature. As an outcome, the belief among mycologists is quite widely held that conidial stages are of rare occurrence. But it seems reasonable to suspect that conidial stages are equally as prevalent among cup-fungi as among other ascomycetes.

Lamprospora trachycarpa, when grown on substrata of widely differing composition, exhibits such pronounced differences in color and amount of mycelium as to make one suspect that he is dealing with more than one species. Partial explanation, however, may reside in the fact that none of the media employed to grow this fungus may provide adequately for its nutrition. The fact that media containing tryptophane, soil extract, or yeast extract favor conidial production is interpreted to mean that this fungus requires an exogenous source of tryptophane or of some other growth factor.

Certainly the conidial stage of *Lamprospora trachycarpa* is among the Moniliaceae. But its structural features, when traced in artificial keys, indicate that it does not agree well with any genus within this family, yet is most nearly like *Rhinotrichum*. Apparently dendroid conidiophores have not been noted among species of this genus. Instead they are little-branched in all described species. When the fungus under consideration herein is seen from above with the low power of a microscope it shows that there are typically 50–100 branches with conidiferous tips. These tips are closely oriented and are densely covered with conidia. If for any reason, however, the conidiophores are depauperate, as occurs when the medium becomes exhausted or when relative humidity is low, then they are small and sparingly branched and are much less copiously covered with conidia. Luxuriance of branching and of conidial production do not appear to constitute adequate features for excluding this fungus from Rhinotrichum. But this opinion remains tentative and must await support that can come only from

extensive studies of cultural characteristics of species now recognized as being members of this genus. For the present, this conidial stage is being designated *Rhinotrichum trachycarpum*, a hitherto unnoticed stage in the developmental cycle of the widely distributed operculate discomycete, *Lamprospora trachycarpa*.

On the basis of the foregoing observations it is essential to emend the description of *Lamprospora trachycarpa* as depicted by Currey. The following brief Latin emended description summarizes its morphologic characteristics as presently known:

Lamprospora trachycarpa (Curr.) Seaver

Prima aetate orbicularis, fere plana, et saepissime umbilicata; demum irregularis, recurva et undulata; discus nigro-fucus, asper et tuberculatus. Cupula 0.5–3.0 cm lata, solo adpressa, extrincicus minute granulata, sessila vel substipitata vel obconica. Ascis cylindraceis vel subcylindraceis, 250–300 × 16–20 μ. Paraphyses biformes; aliae filiformes, apicem versus aliquanto clavatae; aliae latae et pallide fuscae; ascis vacuis simillimae. Hae fere multum corrugatae, hymenii sectioni aspectum mirum sub microscopio praebentes. Ascosporis uniseriatis, penitus globosis vel subglobosis, verrucosis, luteo-brunneis vel fuscis, 15–18 μ latis. Supra solum deustum. Ascosporae licet sub microscopio fuscae, supra chartam nigram demissae albo-griseae sunt.

Status conidicus est *Rhinotrichum trachycarpum*. In cultis hyphis sterilibus repentis, ramoso-intricatis, septatis, imprimis albidis et densiuscule aggregatis, demum luteo-brunneis vel nigris, et crustatis; hyphis fertilibus erectis, pauco-ramosis aut dendriticis, ad apices bis terve furcatis, conidiis lateraliter gerentibus, ex denticulis oriundis dense aggregatis, levibus, dilute obscuris vel fuscis, 4.6–7.2 μ diam. Hab. ad terram humidam abunde suppletam apud materiam organicam.

SUMMARY.—Conidia are produced in cultures derived from ascospores of the operculate cup-fungus *Lamprospora trachycarpa*. This conidial stage most closely resembles the moniliaceous genus *Rhinotrichum*. Its conidiophores are copiously dendritically branched and the spherical conidia are borne singly at the tips of sterigmata that arise on the terminal portions of the branches.

Tryptophane seems to be required for the production of conidia.

It seems probable by use of cultures that conidial stages will be found to be of common occurrence among operculate Discomycetes.

LITERATURE CITED

BREFELD, O. 1891. Ascomyceten II. Unters. Gesammt. Geb. Mykol. **10:** 157–378. (vide pl. 13, figs. 19, 20, 24–26).

CURREY, FREDERICK. 1864. Notes on British fungi. Trans. Linnean Soc. London. **24:** 491–496. (vide p. 493).

DODGE, B. O. 1937. The conidial stage of *Peziza pustulata*. Mycologia **29:** 651–655.

SCHNEIDER, ROSWITHA. 1954. *Plicaria fulva* n. sp. ein bisher nicht unbekannter Gewachshaus-bewohner. Zentrb. f. Bakt. Parasitenkunde Infek. Krankh. u. Hygiene. Abt. II. **108:** 147–154.

SEAVER, F. J. 1942. North American Cup-Fungi (Operculates). 375 p., New York:

WOLF, F. A. 1957. Is Mycotypha a phycomycete? Mycologia **49:** 280–282.

A HALOPHILIC *ENTEROBRYUS* IN THE MOLE CRAB *EMERITA TALPOIDA* SAY

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In a brief survey of literature on marine fungi, Wolf and Wolf (1947) made reference to Eccrinales in the mud crab, *Panopeus herbstii* Milne-Edwards, and in the mole crab, *Emerita talpoida* Say. No descriptions of the eccrinids were given; they were merely assigned to the genus *Enterobryus* as unnamed species. The report by Wolf and Wolf was not the first of Eccrinales occurring in coastal-inhabiting animals. Poisson (1929), for example, described eccrinids in beach fleas of the genera *Orchestia* and *Talorchestia*.

In 1957, we collected in the seaward intertidal zone of Bogue Banks, North Carolina, and in the vicinity of the Duke University Marine Laboratory, Beaufort, both mole and mud crabs infested with eccrinids. These marine crustaceans harbor at least two different eccrinid species. Since the fungus in *Emerita talpoida* (♀) was the most abundant, we subsequently limited our study to this organism. The morphology of assimilative and reproductive stages of the eccrinid are described. We have concluded that the fungus in mole crabs is an undescribed species of *Enterobryus*, for which we propose the name, *halophilus*.

Emerita talpoida (mole crab, mole shrimp, sand bug) is a small, sandy-brown, marine crustacean inhabiting the wave-washed sands in the intertidal zone. The animals burrow in beach sands at the edge of the tidal water line and move rapidly from one burrow to another as wave action washes the beach. Mole crabs survive intermittent immersion in sea water, but die very quickly if subjected to prolonged submersion. In the laboratory, these crustaceans may be kept alive for several days by placing them in shallow dishes of beach sand through which raw sea water is flushed continually.

Enterobryus halophilus is capable of colonizing the entire hindgut of *Emerita talpoida*, but is particularly abundant on the posterior portion of the chitinous intestinal lining around the anal opening. Occasionally, the fungus may be found attached to the internal hairs around the intestinal orifice, and, rarely, external to the animal in a very narrow zone around the anus. Hyphae of the eccrinid are usually not visible in the intact animal because the elongated telson and sixth abdominal segment are recurved and lie closely appressed to the underside of the crab's body. If the mole crabs are placed in jars of sea water, they soon die, thereby facilitating location of filaments after the abdominal musculature has relaxed. If the dead crustaceans are left in sea water for one or two days so that decomposition is initiated, the eccrinid-infested intestinal lining can be easily removed intact from the animals. Lichtwardt (1954) recommended the use of dilute lactophenol for loosening the chitinous intestinal lining of Arthropods. This method has been employed successfully with the *Emerita*. Hyphae of the eccrinid are more satisfactorily prepared for microscope slide mounts if left intact on the chitinous lining. We have studied both stained (according to the two procedures suggested by Lichtwardt, 1954) and unstained preparations of the *Enterobryus*. Living specimens for observation were mounted in filtered, raw sea water in Van Tieghem cells.

Mature filaments of *Enterobryus halophilus* are hyaline, curved or sparingly coiled (Fig. 36), and attached to the substratum by a basal holdfast (Fig. 1, 36). It is not uncommon to observe such hyphae with dense aggregations of coccoid bacteria massed around the distal half of the filament or in the vicinity of the holdfast. The immature assimilative filaments are usually moderately vacuolate, and with staining, show the presence of large nuclei (Fig. 1). As the assimilative hyphae reach maturity, just prior to sporulation, they exhibit very diffuse cytoplasm, and may contain numerous, minute, refractive oil bodies. The vacuoles are indistinct. Apically, the mature filaments bear a hyaline cellulose plug. Viewed laterally, this plug appears truncate on the outer extremity and deeply concave on the inner surface (Fig. 13–16). The portion of the

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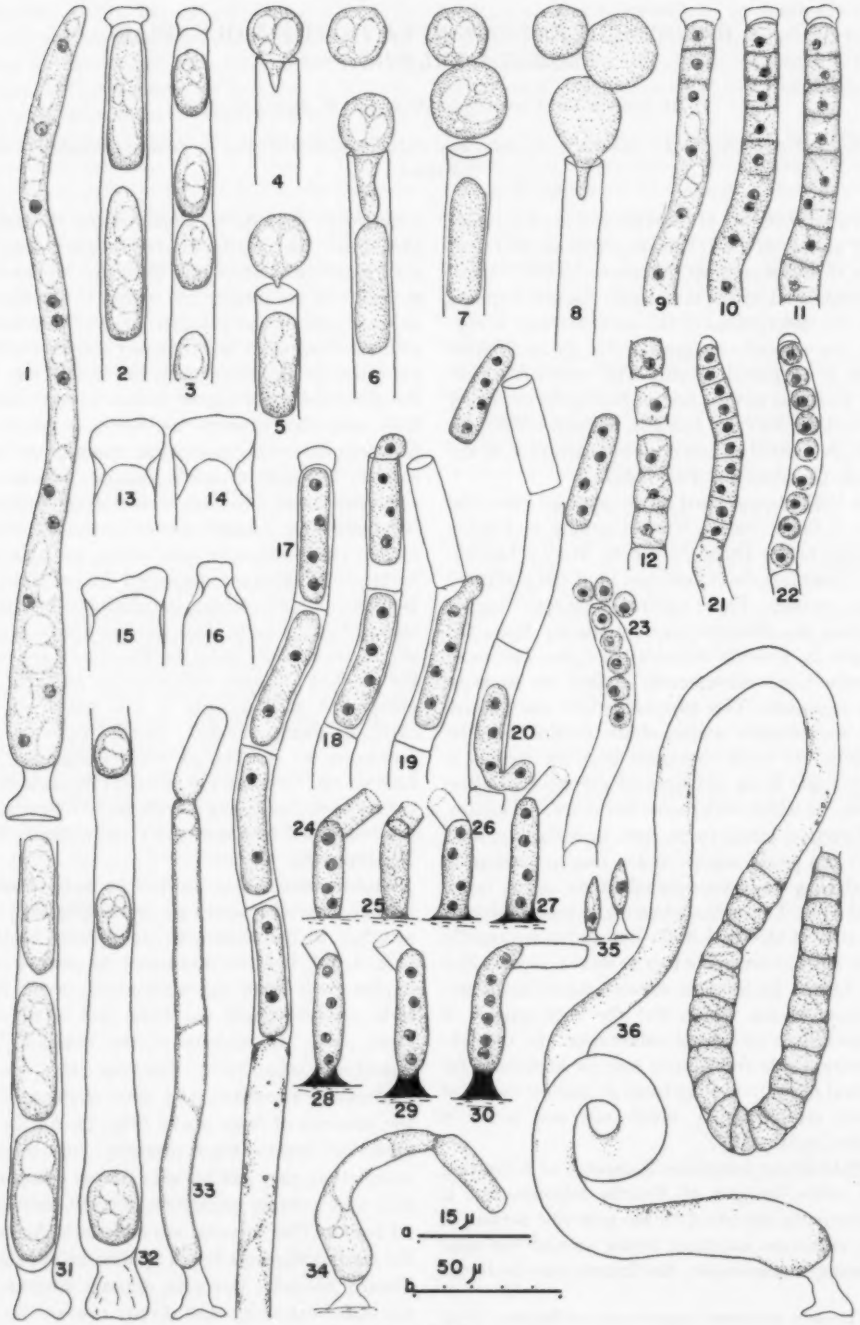
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a 15 μ
b 50 μ

FIGS. 1–36

plug outside the hypha is often somewhat larger (Fig. 13, 15) than the part within the hypha. The apical plug appears to be attached to the filament by two walls (Fig. 13). The outer wall is that of the hypha, while the inner, concave wall is a part of the plug itself. Although the apical plug is not "hinged" in any way to the hyphal tip, it does resemble an operculum in its manner of release from the filament.

Hyphal length of *Enterobryus halophilus* is extremely variable. Considering only discharged filaments (presumably matured before spore discharge), the length ranges from 200 μ to 4.5 mm. Generally, the filaments are 0.8–1.5 mm. long. The basal portion of most filaments is of a greater diameter (Fig. 1, 36) than the apical portion. Only occasionally are filaments of equal diameter throughout (Fig. 33). Diameters (at the widest portion of the hyphae) range from 8 μ to 28 μ; the hyphal apices are less variable, generally ranging from 10–15 μ in diameter. Very slender filaments can sometimes be detected among the more characteristic ones. The holdfast "stalk" is hyaline, slightly constricted laterally (Fig. 34, 36), and ranges from 9–18 μ in length. Occasionally the holdfasts are faintly wrinkled. The base of the holdfast almost invariably conforms to the configuration of the animal tissue to which it is attached. On the intestinal lining, the base is discoid or nearly so (Fig. 1), but on anal hairs, for instance, the basal portion of the holdfast is deeply concave (Fig. 31) or bifurcate.

Three types of spores are produced by the *Enterobryus* commensal in *Emerita talpoida*. These spore types are similar to three of the five types described by Lichtwardt (1954) as being characteristic of the genus *Enterobryus*. Spore type "A" is a cylindrical or oblong-ellipsoid cell. These spores are produced within the hypha as individual units delimited from one another by transverse or occasionally by oblique cross walls (Fig. 17). Each delimited unit of the hypha is a one-spored sporangium. Depending on the stage of maturation, the spore may contain as many as eight nuclei. Spore type "A" is the macrospore, macroconidium, or sporangiospore (Lichtwardt, 1954, p. 570).

Formation of sporangiospores and subsequent delimitation of the sporangia containing these spores follows the pattern described by Lichtwardt (1954) for *Enterobryus elegans* except that the terminal spore escapes, apparently, by forcing the apical plug from the end of the hypha (Fig. 18). Spores in sporangia below the apical one escape by dissolution of the proximal or distal lateral wall of the sporangium (Fig. 19, 20). The emerging spores may partially or completely dislodge the distal sporangia (Fig. 20). Lichtwardt (1954) reported that the sporangiospores of *E. elegans* have one bulbous end and that the enlarged end emerges first from the sporangium. Sporangiospores of *E. halophilus* do not seem to have a bulbous portion, and can apparently emerge (except for the distal spore) from either end of the sporangium.

Released sporangiospores settle on the intestinal membranes of the mole crab and germinate. The end of the spore that first emerges from the sporangium apparently functions in attachment of the spore to the chitinous material of the animal. A rudimentary holdfast may (infrequently) be observed on sporangiospores as they emerge from the sporangia. Shortly after the spore contacts the animal tissue, the end in contact flattens out (Fig. 24, 25). This flattened portion is the rudiment of the holdfast. The holdfast material (callose) is ostensibly "secreted" from the base of the attached spore germ tube (Fig. 26–30). As the holdfast develops, the sporangiospore germinates further and initiates the new hypha (Fig. 24–30, 33, 34).

The rudimentary hypha develops generally by formation and subsequent elongation of a germ tube from the spore (Fig. 24, 25). The mode of hyphal development in *Enterobryus halophilus* is in agreement with the sequence of development

FIG. 1–36. *Enterobryus halophilus*. Fig. 1. Young hypha with discoid basal holdfast. Fig. 2, 3. Cytoplasmic segments in hyphal apices. Fig. 4–8. Stages in discharge of cytoplasmic segments. Fig. 9–12. Stages in formation of oidia. Fig. 13–16. Variations in hyaline, apical plug. Fig. 17. Distal portion of hypha showing sporangia and enclosed sporangiospores. Fig. 18–20. Stages in discharge of sporangiospores. Fig. 21–23. Stages in formation and discharge of endoconidia. Fig. 24–30. Formation of holdfast and germination of sporangiospores (only the basal portion of the germinating sporangiospore is shown in each instance). Fig. 31, 32. Proximal ends of hyphae with enclosed cytoplasmic segments. Fig. 33. Young hypha without basal swelling. Note the apical sporangiospore partially delimited from the filament. Fig. 34. Immature hypha with sporangiospore attached. Fig. 35. Two ellipsoid thalli with holdfasts. Fig. 36. Mature hypha with catenulate, distal oidia. Fig. 13–16, scale a; others, scale b.

described by Lichtwardt for *E. elegans*. For this species, Lichtwardt reported that the rudimentary hypha develops only from a portion of the sporangiospore, and that the elongating hypha is subsequently delimited from the spore case which eventually disintegrates. Only very rarely have we observed sporangiospore germination in the marine *Enterobryus* of a type where the entire spore elongates before actual germination.

Spores similar to those designated as Type "C" by Lichtwardt (1954, p. 570) are also produced by the *Enterobryus* on *Emerita*. These spores, analogous to oidia or conidia, are formed by successive basipetalous cleavage of the apical portion of a hypha (Fig. 9–11). The oidia, as they are termed by Lichtwardt, are uninucleate and vacuolate. They are released from the hypha by fragmentation (Fig. 12), but a portion of the original hyphal wall (Fig. 12) adheres to the free oidia. Germination of the oidia has not been observed; their function in development and spread of *E. halophilus* is unknown.

Enterobryus halophilus occasionally produces a third spore type that is essentially analogous to the type designated as "B" by Lichtwardt (1954, p. 570). He regards these spores as endoconidia, although other investigators of Eccrinales have called such spores microconidia or microspores. Endoconidia of *E. halophilus* develop only in a short, distal segment of the hypha. At first, the rudimentary endoconidia are delimited as catenulate cells, the walls of which appear to be confluent with that of the containing hypha (Fig. 21). Within a few hours after the uninucleate segments are cleaved from the cytoplasm within the hyphal tip, they round up (Fig. 22) as separate units. No septa are in evidence between the spherical endoconidia. The apical plug of the hypha is apparently forced off, and the endoconidia emerge slowly through the resulting orifice. The endoconidia tend to cluster (Fig. 23) in the vicinity of the discharge pore; their germination has not been observed and their function in further development of the fungus is unknown. As far as we could determine, the endoconidia are nonmotile. Nevertheless, their formation in and subsequent discharge from the parent hypha is certainly suggestive of planospore development in some of the aquatic Phycomycetes.

We have observed, rather infrequently, small, ellipsoid thalli (Fig. 35) on chitinous intestinal linings of *Emerita* on which hyphae producing endoconidia are abundant. It is possible that the ellipsoid thalli are the result of endoconidia germination.

Cytoplasm in the hyphae of the *Enterobryus* in the mole crab may become entirely converted into oblong-ellipsoid, obovate, ovate, cylindrical, or spherical segments (Fig. 2, 3, 31, 32). These cytoplasmic bodies represent what may be tentatively designated as a fourth "spore" type. In such instances of "spore" formation, the entire hypha functions as a one-celled "sporangium". The segments (Fig. 2, 32), varying considerably in size, are multinucleate and vacuolate. We have not been able to observe stages in the formation of these cytoplasmic segments. Discharge is initiated as the first unit in the hypha dislodges the apical plug from the end of the filament. The segments constrict slightly as they emerge from the hypha, but round up shortly after being freed from the confining orifice (Fig. 6, 7); they are often attenuated basally (Fig. 4, 6) as they progress through the apical pore. Successive cytoplasmic segments emerge from the hypha, with those still enclosed (Fig. 6, 7) moving slowly upward along the length of the hypha. All the units ultimately aggregate in a loose cluster outside the hyphal orifice (Fig. 8). The process of discharge is not necessarily a continuous one. In some instances, 10 or 15 minutes may elapse between the emergence of one spore and the next. Complete discharge from hyphae mounted in sea water in Van Tieghem cells generally requires a period of 45 minutes to 1½ hours. The nonmotile cytoplasmic segments did not germinate, hence their position in the reproductive cycle of the *Enterobryus* has not been resolved.

We may suggest, based only on inferential evidence, that the spore-like cells developing as cytoplasmic segments are analogous to sporangiospores. These segments differ from sporangiospores, however, in mode of formation and discharge, and in the fact that they originate in hyphae that do not become septate as the spores are delimited.

Classification of the Eccrinales is somewhat less than adequate, despite the attempts by such investigators as Duboscq, Léger and Tuzet (1948), Manier (1950), and Tuzet and Manier (1952) to put the order on a sound taxonomic basis. The publication by Lichtwardt (1954) has done much in the way of establishing sound morphological information about eccrinids, and can very likely become the basis for new interpretations of the order. Of course, the inherent

difficulties in finding developmental stages of eccrinids and making observations on them contribute to the inadequate taxonomic concepts of these fungi. The discovery of an eccrinid that produces posteriorly uniflagellate planonts (Professor Ralph Emerson, communication) may well serve to clarify much of the phylogenetic interpretations proposed for these curious fungi. On the other hand, interpretations of the several spore types produced by individual species of eccrinids are as yet far from resolved. The many gaps that thus exist in knowledge of developmental and reproductive stages, furthermore, makes identification of eccrinids difficult and enigmatical. In our opinion, however, despite inadequate fundamental comparative literature, the eccrinid on *Emerita talpoida* is a species new to science.

Enterobryus halophilus sp. nov. Fig. 1–36.

Hyphae hyalinae, sinuosae vel interdum in se reflexae, vacuolatae, 200 μ—4.5 mm., plerumque 0.8–1.5 mm. longae, basi bulbosae (8–28 μ diametro) apice plerumque 10–15 μ diametro, et obturaculo crasso truncato et hyalino finitae. Retinaculum hyalinum, a latere concavum, 9–18 μ longum, interdum disco basali finitum. Sporangiosporae cylindricales vel oblongo-ellipsoidales, hyalinae, 35–58 × 8–14 μ, ex foramine laterali ad terminum sporangii vel proximum vel ultimum evenientes. Sporangia divisione hyphae formata. Oidia dolioformia vel oblonga, hyalina, uninucleata, 8 × 11 μ usque ad 14 × 17 μ, ordine ab apice ad basim abstricta. Endoconidia globosa, hyalina, uninucleata, 6–9 μ diametro, apice hyphae generata et per foramen apicale emissa. Cytoplasma hyphae se dividit in massulas 15–45 × 11–16 μ, oblongo-ellipsoidales, obovatas, ovatas, cylindricales vel globosas, hyalinas, quae ab apice hyphae emissae, postea globosae factae, sed officio incognito.

Hyphae in intestino posteriori Emeritae talpoidae Say, Bogue Banks, North Carolina, June 18, 1957 (Type).

Enterobryus halophilus most nearly resembles *E. inflatus* (Duboscq, *et al.*, 1948) particularly in the common feature of the bulbous or expanded hyphal base. Both species produce essentially similar sporangiospores (macroconidia) and endoconidia (microconidia). Furthermore, certain hyphae of *E. inflatus* develop uninucleate, elongate endospores that are very suggestive of the cytoplasmic segments (Fig. 2, 31) produced by *E. halophilus*. Whether these "spores" are actually analogous is purely conjectural. Hyphal diameter and length of these two species are very much different; the hyphae of *E. inflatus* are consistently longer and narrower than those of *E. halophilus*. Judging from the description and illustrations of *E. inflatus*, the species does not have a hyaline apical plug, but such a structure is universally present in mature filaments of *E. halophilus*. *Enterobryus inflatus* produces thick-walled resting spores ("spores durables") in the terminal end of assimilative hyphae. Each resting spore is separated from the adjacent one by a transverse septum. No such spores occur, as far as we can determine, in the *Enterobryus* from mole crabs.

Eccrina flexilis produces large, elongate spores that resemble sporangiospores but are not separated by septa. These spores bear a slight resemblance to the large, ovoid cytoplasmic segments produced by *Enterobryus halophilus*. Other features of *E. flexilis* (Duboscq, *et al.*, 1948) differ markedly from those of *E. halophilus*. A thick apical "cap" is in evidence on the distal portion of *Trichella pilhydri* hyphae (Poisson, 1931), and in this respect, it has a characteristic in common with *E. halophilus*. In other features, however, *T. pilhydri* is quite readily separable from the *Enterobryus* in *Emerita*. Neither *Taeniellopsis orchestiae* nor *T. flexilis* (Poisson, 1929) bear more than a superficial resemblance to *E. halophilus*, although both occur in beach-inhabiting Amphipods.

Certain characteristics of *Enterobryus halophilus* warrant emphasis because of their probable bearing on the development and reproduction of the fungus. A critical study of the large cytoplasmic segments is needed to establish the function of these spore-like bodies in the reproductive cycle. It is possible, of course, that these segments are not spores but are merely artifacts developed as the result of some physiological stress brought about by immersion of the fungus in sea water. In the same connection, it is equally possible that the singular mode of discharge of these segments is also induced by some unknown or unintentionally established artificial condition in the laboratory. On the other hand, the frequency with which cytoplasmic segmentation occurs and the consistency in mode of discharge may make the possibility that the segments are artifacts less likely, in our opinion. The cytoplasmic segments develop and are discharged, in the manner previ-

ously described, in sea water, but either fail to develop or fail to emerge from the hyphae when these are mounted in fresh water. We are aware, of course, that this observation is no conclusive argument to be offered as evidence that these segments are not artifacts.

The function and, indeed, the structure of the small, spherical endoconidia (Fig. 23) must also be determined. The superficial resemblance of these spores of *Enterobryus halophilus* to planonts of Phycomycetes is undeniable, but whether the endoconidia are flagellated, perhaps only under certain conditions, must await further study. In the same manner, the oidia (Fig. 12) of *E. halophilus* are yet to be placed, functionally, in the reproductive cycle of the fungus. Methods of inducing germination of the endoconidia and oidia must be devised before the true nature of these spores is manifested.

Nothing is known of the environmental factors favoring development and spread of the eccrinid in *Emerita talpoida*. Similarly, the distribution of the fungus is unknown other than the fact that it occurs in abundance in the Beaufort, North Carolina area. The percentage of infested animals can be quite high. In 1957, for instance, 100 per cent of 81 female *Emerita* in one collection were infested by the *Enterobryus*. In a second collection of 63 females, 88 per cent were infested. In early June, 1958, 66 per cent of 51 females harbored the fungus. Although we have examined a fairly large number of males of the crab species, we have not observed any infestation. *Emerita talpoida* males are most abundant in the months from November through about April on the Carolina coast. Since our collections have been largely limited to the late spring and summer seasons, we cannot conclude that males do not become infested with the *Enterobryus*.

We wish to emphasize that while mole crabs seemingly harbor only one species of eccrinid, other marine Arthropods are infested with such fungi as well. The common mud crab, *Panopeus herbstii*, for example, has an eccrinid colonizing the intestinal lining. The fiddler crabs, *Uca pugnax* S. I. Smith and *U. pugilator* Bosc, harbor different Eccrinales. These fungi invite critical investigation.

Summary

Enterobryus halophilus (Eccrinales), occurring on the intestinal lining of the hindgut of the marine mole crab, *Emerita talpoida* Say, is described. The fungus produces three spore types: sporangiospores, oidia, and endoconidia. In addition, segmentation of hyphal cytoplasm results in spore-like cells; their function is unknown. Only the sporangiospores are definitely known to function in the reproductive cycle of the fungus. The percentage of *Emerita talpoida* females colonized by the *Enterobryus* is high; males are not known to harbor the fungus. The occurrence of other members of the Eccrinales in marine Arthropods is noted briefly.

Acknowledgments

The financial support of the National Science Foundation, through Grant G-2324, and supplementary funds from the Duke University Council on Research, is gratefully acknowledged. We are especially indebted to Dr. R. W. Lichtwardt for his opinions and criticisms of the manuscript, and for his helpful suggestions. Mr. Thomas M. Simkins, Jr., Duke University Library, very kindly prepared the Latin diagnosis.

LITERATURE CITED

Duboscq, O., L. Léger and Odette Tuzet. 1948. Contribution à la connaissance des Eccrinides. Les Trichomycètes. Arch. Zool. Exp. Gén., **86**: 29–144.

Lichtwardt, R. W. 1954. Three species of Eccrinales inhabiting the hindguts of millipeds, with comments on the eccrinids as a group. Mycologia, **46**: 564–585.

Manier, Jehanne-Françoise. 1950. Recherches sur les Trichomycètes. Ann. Sci. Nat. Bot. (Ser. 11), **11**: 53–162.

Poisson, R. 1929. Recherches sur quelques Eccrinides parasites des Crustacés, Amphipodes et Isopodes. Arch. Zool. Exp. Gén., **69**: 179–216.

———. 1931. Recherches sur les Eccrinides. Deuxième contribution. Arch. Zool. Exp. Gén., **74**: 63–68.

Tuzet, Odette and Jehanne-Françoise Manier. 1952. Trichophytes commensaux de l'intestin postérieur de Diplopodes du Brésil. Quelques considérations sur les Trichophytes déja décrits infestant les Diplopodes. Ann. Sci. Nat. Zool. (Ser. 11), **14**: 249–262.

Wolf, F. A. and F. T. Wolf. 1947. The Fungi. Vol. II. Wiley: New York.

CHROMOSOME NUMBERS IN MOSSES OF EASTERN NORTH AMERICA[1]

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The notably difficult taxonomy of mosses can be accounted for largely by the almost universal quantitative variation. Not only varieties and species share distinguishing characters, but even genera. In traditional flowering plant taxonomy, where most bryologists receive their basic systematic concepts, such variations are rarely dignified by generic status, yet in mosses these segregates must frequently be recognized. The extremes of variations stand quite independently and only when very large numbers of specimens are studied does intergradation become obvious. Taken alone, two specimens may seem so unlike as to be considered only distantly related, possibly different generically. But too frequently, when additional specimens accumulate, the forms can be linked with intermediates.

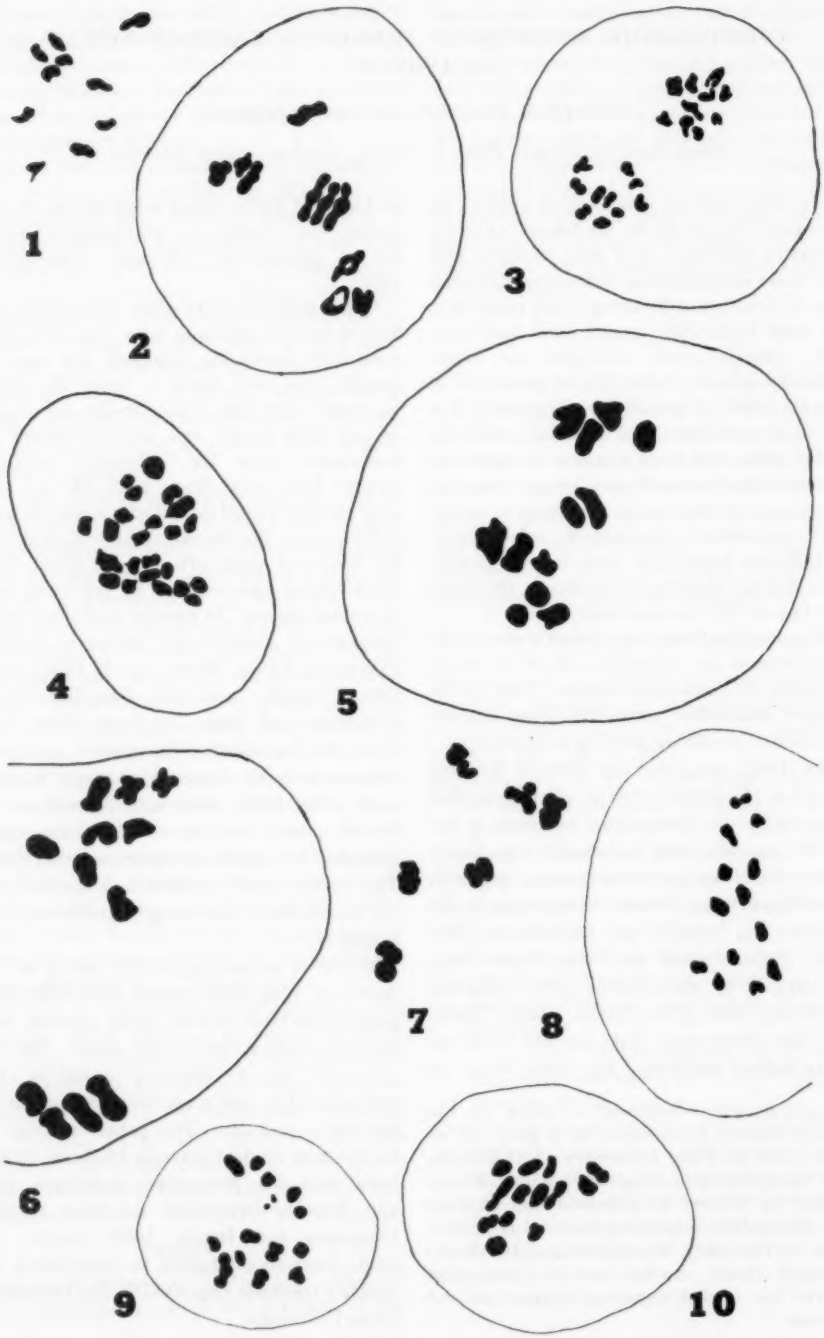
This general problem confronts all taxonomists, but bryologists are plagued with it in nearly every group of mosses encountered. Thus, to the bryologist qualitative characters bring unusual opportunities for solving problem relationships.

Heitz (1942) recognized the value of one such character in the area of cytology when he applied his knowledge of chromosome numbers in the genus *Mnium*. His work was amplified by Lowry (1948) in one of the first cytotaxonomic studies in mosses. Since then, certain relationships in the Fissidentaceae, Ditrichaceae, Dicranaceae, Pottiaceae, Ephemeraceae and Funariaceae have been clarified by chromosome data (Anderson and Bryan, 1956, 1958; Bryan, 1956a, 1956b, 1957). But chromosome data are not a cure-all for bryological problems, any more than for problems of higher plant relationships. In some groups, e.g., *Sphagnum*, chromosome data are not of outstanding systematic value (Bryan, 1955).

In the past ten years while chromosome numbers of moss populations have been surveyed in constantly increasing numbers, not many attempts have been made to apply the data to taxonomic problems. Undoubtedly, the emphasis on reporting mostly raw numbers results from inadequate data for individual systematic groups. Even now, fewer than 500 out of the approximate 18,000 described species are known cytologically. The investigations so far have been, for the most part, attempts to build up our knowledge of chromosomes by surveying mosses of certain regions. At present we have studies of chromosome numbers of mosses in California (Vaarama, 1953a; Steere et al, 1954), Alaska (Steere, 1954), and the Canadian Rockies (Anderson and Crum, in press). Yano (1950–1957) has investigated the meiotic and mitotic chromosomes of Japanese mosses; Vaarama's work (1949–1956) deals with Finnish and also British mosses, and Holmen (1958) has recently published the results of similar studies in Sweden. This survey work continues and the accumulating knowledge is increasingly gratifying to systematists.

We have, in carrying on the survey of North American moss chromosomes, since 1952 studied populations from eastern North America, mostly from the southeastern United States. The results presented here we obtained mostly as studies concomitant to our main investigations of cytotaxonomic problems. This paper embodies data for the taxa studied between 1952 and 1956. We have used the preparation technique, optical and drawing equipment described previously (Anderson and Bryan, 1956; Bryan, 1956). Each population studied is represented by a voucher specimen deposited in the herbarium of Duke University.

[1] Grateful acknowledgment is made to the National Science Foundation for a grant of research funds to Duke University (NSF-G23222) which has made this investigation possible. We are indebted to Wilfred B. Schofield and Howard Crum for contributing living material of several species for this study. We express grateful thanks to Howard Crum, who has read the manuscript and who has offered numerous suggestions and criticisms.



FIGS. 1–10

Subclass ANDREAEOBRYA

Order ANDREAEALES

Family ANDREAEACEAE

Andreaea Hedw.

Andreaea rothii Web. & Mohr.

n = 10; Fig. 1

This cytological study is the first for the subclass Andreaeobrya. The specimen was collected in late October by A. J. Sharp from the steep wall of Whitewater Gorge, Jackson County, North Carolina, on the escarpment of the Blue Ridge Mountains. Compared to the cytology of the many known representatives of the Bryales, the differences in *Andreaea rothii* are striking; but equally remarkable are the similarities to the Sphagnales. The sporocytes are large and filled with an opaque, relatively insoluble cell inclusion. Without a prolonged fixation period this substance, as in *Sphagnum*, takes up the stain and obliterates the nuclear material. Consequently, for this species the mounts were prepared using the technique employed for *Sphagnum* (Bryan, 1955).

Ten bivalents occupy the first meiotic metaphase plate. They tend to cohere, and only infrequently are sporocytes seen in which the bivalents are as well spread as shown in figure 1. The chromosomes are nearly the same size, one bivalent appearing slightly larger than the others (Fig. 1).

Chromosome studies have now been made in all of the major "groups" or subclasses of mosses, Sphagnobrya ("Sphagnales"), Andreaeobrya ("Andreaeales") and the Eubrya ("Bryales"). It is a curious thing that no one questions the naturalness of the groupings themselves or, except possibly for *Archidium*, the plants that comprise the groups. The origin or origins of the groups, the degree of relationship they bear to each other as well as to other plant groups, especially the Hepaticae, and the rank accorded each group, however, are all points much debated both by morphologists and bryologists. No agreement is, in fact, in sight.

Comparative chromosome studies among groups as ancient and as unrelated (comparatively) as these moss groups could scarcely be expected to aid much in elucidating phylogenetic problems at this level. Nevertheless, the distinctive but uniform chromosome behavior in *Sphagnum* (Bryan 1955; Holmen 1955) along with the striking constancy of basic chromosome number is certainly suggestive of the homogeneity of morphological features displayed by the group as a whole. The presence of considerable variation in chromosome behavior in the Eubrya also is correlated to some extent with the diverse morphological variations that characterize this complex sub-class. Yano (1957b, c, d), for example, has emphasized unique chromosome characteristics of each of the orders, Fissidentales, Dicranales, Eubryales, Grimmiales, Hypnobryales and Polytrichinales.

The cytological similarities that *Andreaea* bears to *Sphagnum* on the one hand and to the Eubrya on the other, is paralleled in morphological resemblances. In structure of the leafy gametophytic plants and in the mode of origin of sporogenous tissue, *Andreaea* resembles the Eubrya. The more or less strap-like or plate-like protonema and the elevation of the capsule by means of a pseudopodium, however, are features of the Andreaeobrya that resemble the Sphagnobrya.

FIG. 1, *Andreaea rothii* Web. & Mohr, polar view, metaphase I; n = 10. FIGS. 2-3, *Dicranella rufescens* (Sm.) Schimp.: 2, early metaphase I; 3, polar view, metaphase II; n = 10. FIG. 4, *Dicranum flagellare* Hedw., polar view, metaphase I; n = 23. FIG. 5, *Dicranum fuscescens* Turn., early metaphase I; n = 12. FIG. 6, *Dicranum scoparium* Hedw., side view, metaphase I, with chromosomes in two groups; n = 12. FIG. 7, *Leucobryum albidum* (Brid.) Lindb., late diakinesis or early metaphase I; n = 6. FIG. 8, *Weissia controversa* Hedw. var. *australis* Schornh, polar view metaphase I; n = 13. FIG. 9, *Tortella humilis* (Hedw.) Jennings, polar view, metaphase I; n = 15. FIG. 10, *Barbula fallax* Hedw., polar view, metaphase I; n = 13.

(original magnification ×4600, reduced to ×3100)

TABLE 1

Chromosome numbers in species of eastern mosses

	Source of Material	Chromosome number n =	Figs.
ANDREAEOBRYA			
Andreaeales			
Andreaea rothii Web. & Mohr.	Transylvania Co., N. C. Coll. A. J. Sharp	10	1
EUBRYA			
Dicranales			
Dicranella rufescens (Sm.) Schimp.	Stark Co., Ohio	10	2, 3
	Durham Co., N. C.	10	
Dicranum flagellare Hedw.	Gatineau Park, Que. Coll. Howard Crum	23	4
Dicranum fuscescens Turn.	Mitchell Co., N. C.	12	5
Dicranum scoparium Hedw.	Macon Co., N. C.	12	6
	Mitchell Co., N. C.	12	
	Orange Co., N. C.	12	
Leucobryum albidum (Brid.) Lindb.	McDowell Co., N. C.	6	7
Pottiales			
Weissia controversa Hedw. var. *australis* (Aust.) Schornh.	Durham Co., N. C.	13	8
Tortella humilis (Hedw.) Jennings	Durham Co., N. C.	15	9
Hyophila tortula (Schwaegr.) Hampe	Dade Co., Fla.	13	43
Barbula fallax Hedw.	Cape Breton, Nova Scotia Coll. W. B. Schofield	13	10
Grimmiales			
Grimmia alpicola Hedw.	Gatineau Park, Que. Coll. Howard Crum	14	42
Grimmia apocarpa Hedw.	Orange Co., N. C.	14	11, 12
Eubryales			
Bryum argenteum Hedw.	Alleghany Co., N. C.	10	13, 14
	Macon Co., N. C.	10	
Rhizogonium spiniforme (Hedw.) Bruch	El Yunque, Puerto Rico Coll. C. Rossy-Valderrama	6	15, 16
Aulacomnium heterostichum (Hedw.) BSG.	Granville Co., N. C.	12	17
Aulacomnium palustre (Hedw.) Schwaegr.	Orange Co., N. C.	12	18
Bartramia promiformis Hedw.	Durham Co., N. C.	8	19
	Orange Co., N. C.	8	
	Mitchell Co., N. C.	8	
Isobryales			
Ptychomitrium drummondii Sull.	Durham Co., N. C.	13	20, 21
	Randolph Co., N. C.	13	
Orthotrichum ohioense Sull. & Lesq.	Durham Co., N. C.	11	44
Orthotrichum pusillum Mitt.	Durham Co., N. C.	11	45
	Gaston Co., N. C.	11	
	Orange Co., N. C.	11	
Macrocoma hymenostomum (Mont.) Grout	Jackson Co., N. C.	12	22
Cryphaea glomerata Schimp.	Orange Co., N. C.	11	23
Leucodon julaceous (Hedw.) Sull.	Orange Co., N. C.	10	24–28
	Durham Co., N. C.	10	
Hypnobryales			
Clasmatodon parvulus (Hampe) Sull.	Durham Co., N. C.	11	46
	Volusia Co., Fla.	11	

TABLE 1—*Concluded*

	Source of Material	Chromosome number n =	Figs.
Hypnobryales			
Thuidium delicatulum (Hedw.) Mitt.	Macon Co., N. C.	11	30
	Orange Co., N. C.	11	
Thuidium scitum (P. Beauv.) Aust.	Yancey Co., N. C.	11	29
Hygroamblystegium orthocladon (P. Beauv.) Grout	Durham Co., N. C.	20	31
Brachythecium rivulare BSG.	Jackson Co., N. C.	16	32
Cirriphyllum boscii (Schwaegr.) Grout	Durham Co., N. C.	12	33
Rhynchostegium serrulatum (Hedw.) J. & S.	Stark Co., Ohio	9	34
Entodon seductrix (Hedw.) C. Müll.	Durham Co., N. C.	11	35
Plagiothecium denticulatum (Hedw.) BSG.	Yancey Co., N. C.	20	36
Heterophyllium haldanianum (Grev.) Kindb.	Victoria Co., Nova Scotia Coll. W. B. Schofield	22	37
Pylaisia selwynii Kindb.	Durham Co., N. C.	11	38
Hypnum fertile Sendt.	Macon Co., N. C.	11	39
Mittenothamnium diminutivum (Hampe) E. G. B.	Dade Co., Fla.	10	47
Buxbaumiales			
Diphyscium foliosum (Hedw.) Mohr	Durham Co., N. C.	9	48
	Transylvania Co., N. C.	9	
	Mitchell Co., N. C.	9	
	Washtenaw Co., Mich.	9	
Polytrichales			
Atrichum angustatum (Brid.) BSG.	Granville Co., N. C.	7	40
Pogonatum pensilvanicum (Hedw.) Paris	Victoria Co., Nova Scotia Coll. W. B. Schofield	7	41

Subclass EUBRYA

Order DICRANALES

DICRANACEAE

Dicranella Schimp.

D. cerviculata (Hedw.) Schimp.	n = 15	Steere, 1954
D. crispa (Hedw.) Schimp.	n = 15	Steere, 1954
	n = 14	Anderson & Crum, in press
D. grevilleana (Brid.) Schimp.	n = 15	Steere, 1954
D. heteromalla (Hedw.) Schimp.	n = 13	Yano, 1954c
D. subulata (Hedw.) Schimp.	n = 15	Anderson & Crum, in press
D. varia (Hedw.) Schimp.	n = 14	Steere et al, 1954

Dicranella rufescens (Sm.) Schimp.

n = 10; Fig. 2, 3

The chromosome number of this species has not been reported previously and is the fourth representative of *Anisothecium* Mitt., a weak segregate of *Dicranella*, to be studied cytologically. Steere et al. (1954) reported the number, n = 14, for *Dicranella varia* and Steere (1954) found 15 bivalents in *D. crispa*. Thus, in *Anisothecium*, the numbers 10, 14 and 15 are known while in *Dicranella*, 13, 14 and 15 have been reported. Cytological data are apparently of little help in appraising *Anisothecium* as a genus distinct from *Dicranella*, and the morphological grounds for maintaining *Anisothecium* are not strong (Anderson and Crum, in press).

The discovery of this species with a number of ten suggests that the basic number in the genus may be 5, that *D. rufescens* is gametophytically diploid, the n = 15 species are gametophytically triploid and the 14 and 13 races well-established aneuploids in which chromosome morphology has been altered.

Yano (1954c, 1957b) has described the karyotype in *D. heteromalla* as 2V-2V-2J-4v-2j-m. He explains that this complement may be a hypodiploid evolved by the loss of one of the two m's of a euploid (in terms of the gametophyte) complement. In *D. rufescens*, however, we did not observe an m-chromosome and the sizes of the bivalents vary little enough so that we can divide them into only three classes: 4 large, 1 small and 5 intermediate sized chromosomes. At early MI the bivalent configurations are distinct

(Fig. 2), and several good figures of AI were observed that clearly showed 10 chromosomes at each pole (Fig. 3).

Despite the lack of uniformity of chromosome numbers reported in this genus, apparently some hybridization takes place. Wettstein (1932) reports a natural hybrid found in Germany between *D. heteromalla* and *D. cerviculata*. These results must be viewed with reserve because in a putative hybrid that supposedly combines characters of two species it is difficult to rule out the possibility of extreme specific variability. This is especially true in a genus such as *Dicranella*, in which the diagnostic features are not sharply defined.

Dicranum Hedw.

D. caesium Mitt.	n = 11	Yano, 1951b
D. condensatum Hedw.	n = 12	Bryan, 1956b
D. elongatum Schleich.	n = 12	Steere, 1954
D. fuscescens Turn.	n = 12, 24	Anderson and Crum, in press
D. japonicum Mitt.	n = 11	Shimotomai and Koyama, 1932; Yano, 1951b, 1957b
D. majus Sm.	n = 12 + 5	Vaarama, 1950a
	n = 12	Steere, 1954
	n = 11	Yano, 1950, 1951b, 1957a
D. nipponense Besch.	n = 11	Yano, 1950, 1951a, 1957a
D. scoparium Hedw.	n = 10-12	Heitz, 1928
	n = 12	Vaarama, 1950a
	n = 11	Yano, 1951a, 1957c
D. spadiceum Zett.	n = 12	Anderson and Crum, in press
D. spurium Hedw.	n = 12	Vaarama, 1950b
D. strictum Schleich.	n = 12 + 2	Anderson and Crum, in press
D. rugosum (Brid.) Brid. (*D. undulatum* Sturm.)	n = 10— 12	Heitz, 1928
	n = 12	Vaarama, 1950b
	n = 11	Yano, 1951b, 1957b
	n = 12 + 1	Holmen, 1958

Dicranum flagellare Hedw.

n = 23; Fig. 4

Living plants from Gatineau Park, Quebec, were sent to us by Howard Crum. The haploid chromosome number is 23. The bivalents are only about half the size of those of the following two species, yet there was no evidence that the 23 bodies were disjoined bivalents. Meiotic behavior is regular and all of the bivalents disjoin at about the same time at MI. Several investigators (Vaarama, 1950a; Yano, 1951a; Steere, 1954) have described in the complements of species of *Dicranum*, one conspicuously large bivalent, although we have not observed such a condition in any of the species that we studied. In *Dicranum flagellare* four bivalents are slightly larger than the others, but in the other two species investigated, *D. fuscescens* and *D. scoparium*, the chromosomes are remarkably uniform in size.

This is the second polyploid to be described in *Dicranum*. Anderson and Crum (in press) found a single polyploid population of *D. fuscescens* in the Canadian Rocky Mountains, in which the number n = 24, was described, but all of the other nine populations of this widely distributed moss they studied had the number n = 12. The present count of n = 23 for *D. flagellare* is based upon a single population, so additional populations must be studied to determine whether this species also possesses sporophytically diploid races.

The plants of *D. flagellare* from which the counts were made are no larger than usual for the species, and cell size, leaf size and shape, and capsule size and shape are all typical. As a species, *D. flagellare* is certainly not robust, when one compares it, for example, with *D. majus*, *D. scoparium*, *D. spurium* and *D. rugosum*, and on the basis of size and vigor it is probably one of the least likely species in the genus to be suspected of being polyploid. Grout (1904) described var. *minutissimum* of *D. flagellare*, which grows to a height of only a few mm., and occurs mostly in dense soft mats on shaded banks of rivers, drainage ditches and swamps along the Atlantic Coastal Plain and elsewhere in the Southeast. This variety has generally been thought of as an ecological expression of the species, but in the light of the tetraploid nature of the species, it might be revealing to know the chromosome number of var. *minutissimum*.

It will be of unusual interest to learn, from further studies, of the origin of this polyploid, since, as is well known, Wettstein (1924a) and La Rue (1929) failed to get regeneration from any species of *Dicranum*. Thus, polyploid forms in this genus, as in some other mosses (Anderson and Bryan, 1956), probably do not arise through apospory.

Dicranum flagellare, along with *D. strictum*, *D. montanum* and two Japanese species, have been segregated in the genus *Orthodicranum* Loeske. Anderson and Crum (in press) feel that there is little justification for the genus and their studies of *D. strictum* showed no cytological evidence for the separation. After studying *D. flagellare* we feel that we must agree with the discussion of Anderson and Crum.

Dicranum fuscescens Turn.

n = 12; Fig. 5

This variable species is close taxonomically to *D. scoparium* and *D. condensatum*. It is commonly found in the mountains, but also in the Piedmont where it never assumes its typical development (Anderson, 1939). Our material came from the Mountains and we observed 12 large bivalents at first metaphase. This count agrees with the number found by Anderson and Crum (in press) in a population from the Canadian Rockies.

Dicranum scoparium Hedw.

n = 12; Fig. 6

The large and attractive *D. scoparium* occurs in a wide range of habitats, and is one of the most easily recognized of the *Dicrana*. The 12 large bivalents are extremely cohesive, so that the first metaphase figures are difficult to interpret. Frequently numbers of more than 12 are found but these represent both bivalents and half-bivalents.

Thirteen species of *Dicranum* have now been studied cytologically. Almost all are members of the subgenus *Eudicrana* Mitt. However, the chromosome numbers are not helpful in determining relationships within the group. Possibly worth pointing out is the fact that for Japanese populations 11 chromosomes have been reported while Finnish and North American populations have the number n = 12. There is certainly no cytological support at present for generic segregation into *Arctoa*, *Kiaeria*, *Dicranum*, and *Orthodicranum*. For a more detailed discussion of the problem, see Anderson and Crum (in press).

LEUCOBRYACEAE

Leucobryum Brid.

L. glaucum (Hedw.) Schimp.	n = 14	Ho, 1956
L. textori Besch.	n = 11	Yano, 1957b

Leucobryum albidum (Brid.) Lindb.

n = 6; Fig. 7

The first member of the genus to receive cytological attention was *L. glaucum* (Ho, 1956). The gametophytic cells in mitosis were reported to have n = 14. Another species, *L. textori* showed 11 gametophytic chromosomes (Yano, 1957b) in sterile material. Of the 11 chromosomes the largest and the smallest were heteropycnotic. Yano observed that the morphology and heteropycnosis of these chromosomes are similar to the corresponding chromosomes of *Dicranum*. Outstanding differences can be seen in the sets illustrated by Yano and the set shown by Ho. The latter includes neither an outstandingly larger chromosome nor an m-chromosome. The orientation of six of these very small, thin chromosomes gives the impression that they could actually represent the arms of three chromosomes; if so, the space between each pair of arms is the kinetochore. This possibility suggests that *L. glaucum* might also have the number n = 11; further studies are needed to establish the number with certainty.

Our investigation of a third species of this genus, *L. albidum*, sheds little light on the problem since this species has 6 chromosomes. It may be worthwhile noting here, that several genera that contain races of n = 11, also have races of n = 6 (*Orthotrichum*, *Heterophyllium*, *Hypnum*, and *Hylocomium*).

The meiotic configurations in *L. albidum* resemble those in certain representatives of the *Dicranaceae*, notably *Bruchia*, *Trematodon*, *Dicranella*, and *Dicranum*. This similarity probably reflects the relatively close relationship of the two families. The staining properties and cohesiveness of the bivalents are particularly similar. However, the shape of *Leucobryum* bivalents at first metaphase is quite unusual, and when making early studies we were under the impression that the bivalents were in secondary association. More intensive study, especially of later stages, showed that the six bodies present at first metaphase are bivalents.

The clear-cut difference in chromosome number between *Leucobryum albidum* and *L. glaucum* is surprising in view of their close morphological resemblances. The differences are mainly quantitative: *L. glaucum*, as one might expect in the polyploid, is larger and more robust, with broader and longer leaves and with larger leaf cells. There appears to be no sexual difference between the two species, however, in spite of the evident monoploid-diploid relationships of the respective gametophytes. Both species are dioicous, with tiny male plants epiphytic on the larger female plants. Male plants are anchored to the tomentum and are sometimes enclosed by the perichaetial leaves.

Order POTTIALES

POTTIACEAE

Weissia Hedw.

W. controversa Hedw. (*W. viridula* Hedw.)	n = 14	Vaarama, 1950b
	n = 13	Sannomiya, 1955; Steere et al., 1954; Bryan, 1956a
W. longidens Card.	n = 13	Sannomiya, 1955

Weissia controversa Hedw. var. *australis* (Aust.) Schornh.

n = 13; Fig. 8

This robust variety from the southeastern United States is, in its fullest expression of characteristics, very distinct from the species. But, *W. controversa* is a variable species and the line between the varietal form and the specific is difficult to construct. The chromosomes, as seem to be usual at the varietal level, present no evidence for the separation of the variety. Using chromosome number and morphology and considering only the better preparations by the same technique, one cannot distinguish cytological mounts of the variety from those of the species. In addition, as pointed out previously (Bryan, 1956a), the chromosomes strongly resemble those of *Astomum ludovicianum* and *A. muhlenbergianum*. Andrews (1933) stresses the lack of a clear natural line between these related genera.

Tortella (C. Müll.) Limpr.

T. tortuosa (Turn.) Limpr.	n = 13	Anderson and Crum, in press

Tortella humilis (Hedw.) Jennings

n = 15; Fig. 9

As Anderson and Crum (in press) found in *T. tortuosa*, the sporocytes of *T. humilis* are much smaller than most moss sporocytes. All of the 15 bivalents are similarly small in comparison with other moss chromosomes and two bivalents are extremely minute. These m-chromosomes are apparently regular members of the *T. humilis* complement, but were not observed in *T. tortuosa* by Anderson and Crum. *Tortella humilis* is autoicous while *T. tortuosa* belongs with a group of dioicous species, and it will be of interest to know whether other species in the autoicous group have the same chromosome number as *T. humilis*. Closely resembling *Tortella humilis*, *T. flavovirens*, which is confined mainly to the Atlantic Coastal Plain, differs from the former mainly in that it is dioicous. A chromosome count of *T. flavovirens* would be highly desirable.

Hyophila Brid.

Hyophila tortula (Schwaegr.) Hampe

n = 13; Fig. 43

No previous counts have been reported for any member of this genus, which is represented in the U. S. only by *H. tortula*. The distribution of this species in North America has been studied recently (Sharp, 1955; Crum and Anderson, 1958). Our cytological material was collected in a Dade County, Florida, hammock where it was found in some abundance. Although widely distributed in Eastern North America, it seldom fruits except in the tropics or near-tropics. We were fortunate, therefore, to be able to obtain such favorable material for study.

The chromosome number n = 13 continues to assume significance in the Pottiaceae. Except for a few high polyploids in *Tortula* and *Phascum* and an occasional tetraploid the number 13 predominates not only in the family but in the order, Pottiales.

Barbula Hedw.

B. brachyphylla Sull.	n = 10	Steere et al., 1954
B. convoluta Hedw.	n = 11	Steere et al, 1954
B. cylindrica (Tayl.) Schimp.	n = 13	Vaarama, 1953b
B. fallax Hedw.	n = (9) 10(11)	Heitz, 1928
B. unguiculata Hedw.	n = 13	Jachimsky, 1935; Vaarama, 1950b; Sannomiya, 1957
B. vinealis Brid.	n = 14	Steere et al., 1954

Barbula fallax Hedw.

n = 13; Fig. 10

This large genus of mosses (about 300 species according to Brotherus, 1924) includes some notoriously variable species, and Steere (1938) thinks about half of the species listed by Brotherus could easily be reduced to synonymy through careful study. As can be seen from the species whose chromosome numbers are known, aneuploidy is the rule in the genus, with the numbers 10, 11, 13, and 14 having been reported. The previous report by Heitz for *B. fallax*, presumably from Germany, was made before improvements in techniques had been made, so it need not be concluded that chromosome number for this species differs in Europe and North America. Additional counts should be made from European populations.

Steere (1938) divides the American species into 9 "fairly natural and distinct groups," but chromosome numbers are not yet known for enough species within any one group to determine possible correlations. Chromosome number is known for more than one species in only one group, Vineales, in which *B. cylindrica* has n = 13 and *B. vinealis* has n = 14. It is likely that no correlations will be found.

Order GRIMMIALES

GRIMMIACEAE

Grimmia Hedw.

G. affinis Hornsch.	n = 13	Anderson and Crum, in press
G. alpestris (Web. & Mohr) Nees	n = 13	Steere et al., 1954
G. alpicola Hedw.	n = 13	Anderson and Crum, in press
var. *latifolia* (Zett.) Möller	n = 13	Anderson and Crum, in press
G. apocarpa Hedw.	n = ca. 20	Heitz, 1928
	n = 12	Vaarama, 1953b
	n = 13	Steere et al., 1954; Ho, 1956; Holmen, 1958
	n = 14	Anderson and Crum, in press
var. *pulvinata* (Hedw.) Jones		Steere et al., 1954;
G. montana BSG	n = 13	Anderson and Crum, in press
G. muehlenbeckii Schimp.	2n = 28 + 4	Vaarama, 1949
G. patens (Hedw.) BSG	n = 22	Yano, 1954c
G. platyphylla Mitt.	n = 14	Steere, 1954
G. trichophylla Grev.	n = 13	Steere et al., 1954; Ho, 1956

Grimmia alpicola Hedw.

n = 14; Fig. 42

Collected at Gatineau Park, Quebec, the specimen from which this count was made was sent to us by Howard Crum. Meiosis in this material, as in other *Grimmias* with which we have worked, was very difficult to understand. The chromosomes are cohesive, yet tend to fragment and to become attenuated at anaphase. Fully aware of the pitfall of precociously disjoined bivalents, we finally arrived at a count of n = 14, although the number n = 13 has previously been reported.

Sayre (1952) regards *G. alpicola* as a variety of the very complex and polymorphous *G. apocarpa*. We have observed the chromosomes of these two species not only in the present study but in other studies (Steere et al, 1954; Anderson and Crum, in press; Anderson and Bryan, unpublished) involving different parts of North America and we can see no differences in chromosomes or meiotic behavior between the two entities and the varieties that either or both of us have studied. The ultimate rank accorded these various taxa will thus have to rest upon morphological, ecological and geographical grounds or, more hopefully, upon genetic studies.

Grimmia apocarpa Hedw.

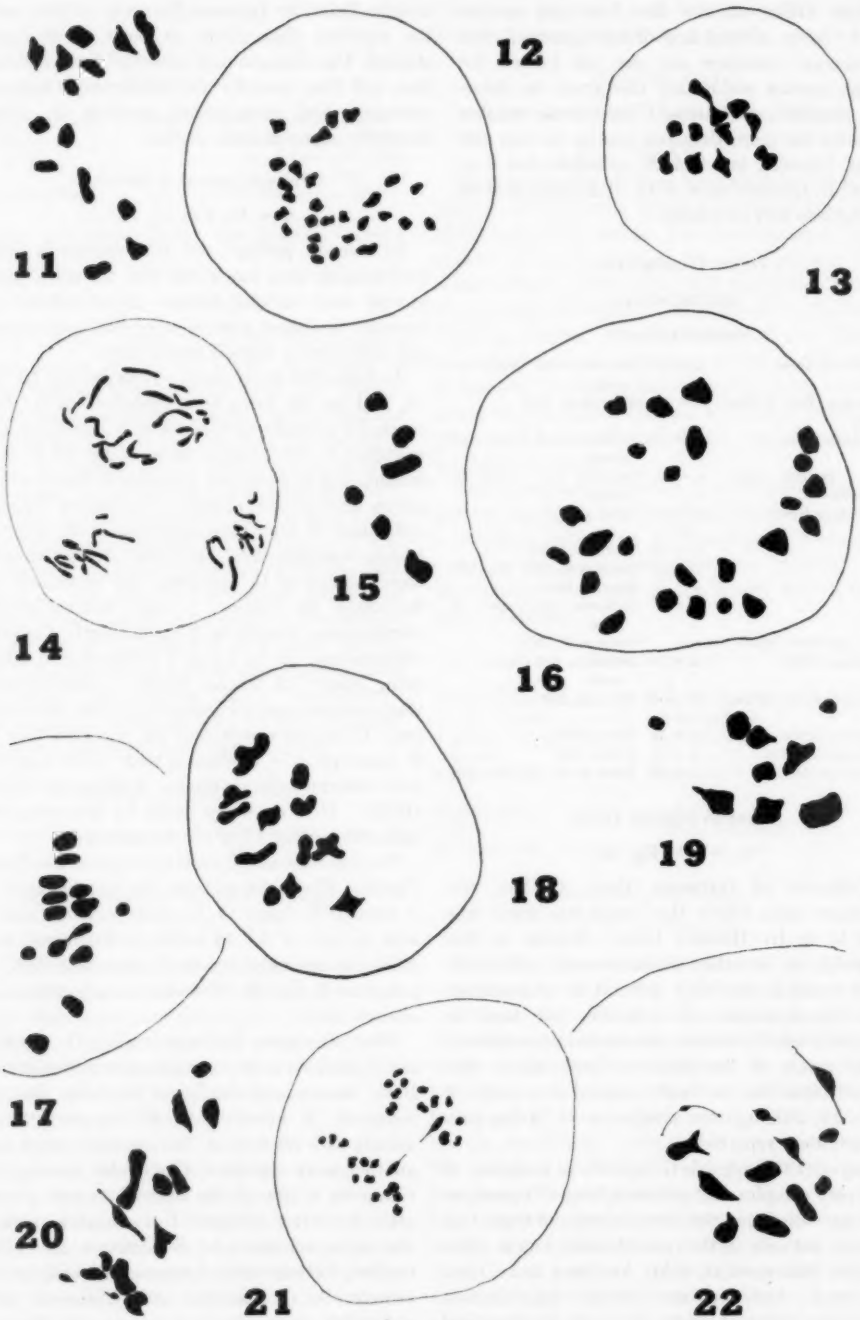
n = 14; Fig. 11, 12

As already pointed out this species is very polymorphic and has given rise to much synonymy and varietal names. An abundance of capsules is almost always available, and during the early spring meiosis takes place.

As indicated above, haploid numbers of 12, 13, 14, and ca. 20, have been reported for *G. apocarpa*. In a species as variable as *G. apocarpa*, the existence of chromosome races would not be surprising, but it is also not improbable that investigators have arrived at different numbers through differences in their interpretations of the difficult meiotic configurations. Ho (1956) studied somatic chromosomes of *G. apocarpa*, and described the karyotype as follows: 1 large heteropycnotic chromosome, averaging 2.2 μ in length; 1 curved chromosome, up to 1.5 μ; 7 chromosomes measuring about 1.2 μ; and finally, 3 chromosomes that measure approximately 0.8 μ. But this totals only 12 chromosomes and Ho reported that in *G. apocarpa*, n = 13, stating that "Cette numeration confirme celle de Steere, Anderson et Bryan (1954)." Ho's drawings could be interpreted as indicating either 12 or 13 chromosomes.

We feel reasonably confident that in the North Carolina Piedmont material the number n = 14 is correct. In figure 11, bivalent structure can be seen in each of the 14 bodies pictured and even more convincingly, figure 12 depicts a SMC at anaphase I, and 28 chromosomes are evident, 14 at each pole.

Most European bryologists place *G. apocarpa* and *G. alpicola* in the segregate genus, *Schistidium* Brid., maintained chiefly on the basis that the columella is attached to the operculum and usually falls off with it. In *Grimmia* proper (and another weak segregate, *Coscinodon* Spreng.) the columella is free of the operculum and persists after the latter dehisces. Unfortunately none of the other members of *Schistidium* have been studied, because the chromosomes and meiotic behavior in *G. apocarpa* and *G. alpicola* differ somewhat from that in species of *Grimmia* proper. Chromosomes in both of these species and



FIGS. 11–22

their varieties are cohesive, they tend to stick together and in clumps and are difficult to spread apart by means of the squash techniques. As pointed out previously, the chromosomes tend to fragment and at least one bivalent disjoins precociously. A satisfactory count at meiosis is difficult to arrive at and is subject to more than the usual amount of interpretation. In contrast, in the species of *Grimmia* proper that we have had experience with, including *G. alpestris*, *G. affinis*, *G. montana*, and *G. trichophylla*, the chromosome configurations are clear and distinct. The individual bivalents are easy to recognize, there is little or no tendency toward clumping, and in the species in which precocious disjunction of one or more bivalents does occur the behavior is straightforward and relatively easy to understand.

We cannot draw conclusions, however, until chromosome studies have been made of other species of *Schistidium*. It is possible that the deviant behavior is confined to the alpicola-apocarpa complex.

Natural hybrids were reported in *Grimmia* by Wettstein (1932), although none is known for either *G. alpicola* or *G. apocarpa*. According to Wettstein, *Grimmia orbicularis* can cross both with *G. tergestina* and *G. pulvinata*. The crosses were not demonstrated experimentally.

Order EUBRYALES

BRYACEAE

Bryum Hedw.

B. arcticum (R. Br.) BSG	n = 20	Steere, 1954
B. argenteum Hedw.	n = 10	Marchal, 1920; Jachimsky, 1935; Yano, 1956, 1957b
	n = 11	Steere, 1954
var. *lanatum* (P. Beauv.) BSG	n = 12	Steere, et al., 1954
B. bicolor Dicks.	n = 10	Vaarama, 1956
B. caespiticium Hedw.	n = 10	Marchals, 1911; Wettstein, 1924b; Wettstein, 1937; Wettstein and Straub, 1942; Yano, 1956, 1957b; Vaarama, 1956
	n = 10 + 1	Vaarama, 1956
	n = 20	Wettstein, 1937; Sannomiya, 1955
B. calophyllum R. Br.	n = 40	Steere, 1954
B. capillare Hedw.	n = 10	Marchals, 1911
	n = 9–10	Heitz, 1928
	n = 10 + 5	Steere et al., 1954
var. "bivalens"	n = 20	Marchals, 1911
B. corrensii F. v. Wetts.	n = 20	Griesinger, 1937; Wettstein and Straub, 1942
	n = 40	Griesinger, 1937
B. cyclophyllum (Schwaegr.) BSG	n = 10	Yano, 1956, 1957b
B. inclinatum (Web. & Mohr) Sturm.	n = 30	Steere, 1954
B. nagasakense Broth.	n = 10	Yano, 1956, 1957b
B. nitidulum Lindb.	n = 20	Steere, 1954
B. pallescens Schleich.	n = 10	Yano, 1950, 1952
B. pendulum (Hornsch.) Schimp.	n = 10	Anderson and Crum, in press
B. pseudo-alpinum Ren. & Card.	n = 10	Yano, 1956, 1957b
B. pseudotriquetrum (Hedw.) Schwaegr.	n = 10	Heitz, 1928
	n = 10 + 1	Steere et al., 1954
	n = 20	Anderson and Crum, in press
B. turbinatum (Hedw.) Schwaegr.	n = 10 + 1	Anderson and Crum, in press
B. ulipinosum (Brid.) BSG	n = 10	Steere, 1954
Bryum sp.	n = 50	Steere, 1954

Bryum argenteum Hedw.

n = 10; Figs. 13, 14

The various numbers reported for material from Belgium, Germany, Japan, California and Alaska raise the question of whether this weedy cosmopolitan species can be supported cytologically by any of an aneuploidic series of numbers. With this question in mind, we have decided to check the chromosome number in many popula-

FIGS. 11–12, *Grimmia apocarpa* Hedw.; 11, polar view metaphase I; 12, anaphase I, with half-bivalents squashed out in flat plane, the 14 half-bivalents from each anaphasic group merged together; n = 14. FIGS. 13–14, *Bryum argenteum* Hedw.; 13, polar view metaphase I; 14, anaphase II; n = 10. FIGS. 15–16, *Rhizogonium spiniforme* (Hedw.) Bruch; 15, side view, metaphase I; 16, telophase II or late anaphase II; n = 6. FIG. 17, *Aulacomnium heterostichum* (Hedw.) BSG, side view, metaphase I, one bivalent has already disjoined, another is shown in the process of disjunction, the remaining 10 bivalents are still in metaphase; n = 12. FIG. 18, *Aulacomnium palustre* (Hedw.) Schwaegr., side view of metaphase I; n = 12. FIG. 19, *Bartramia pomiformis* Hedw., polar view of metaphase I, with one bivalent having already separated into two half-bivalents; n = 8. FIGS. 20–21, *Ptychomitrium incurvum* (Muehlenb.) Sull.; 20, metaphase I, side view, with one bivalent in anaphase; 21, late anaphase I, showing one bivalent with anaphase bridge; n = 13. FIG. 22, *Macrocoma hymenostomum* (Mont.) Grout, polar view, metaphase I; n = 12.

(Original magnification ×4600, reduced to ×3100, except fig. 21, original ×3100, reduced to ×2100)

tions. The population from which this count was made came from the Blue Ridge Mountains, in Macon Co., N. C. It clearly has the gametophytically diploid number of n = 10. All investigators report one large bivalent that is distinctive enough to be immediately recognized in every cell. Figure 14 shows the four basic sets at the conclusion of meiosis. In this species the second telophase chromosomes are remarkably similar to somatic chromosomes, and Yano's (1956) reported karyotype, V-V-2J-2v-3j-m, can usually be identified.

It should be pointed out that putative natural hybrids involving six species of *Bryum* have been reported (Wettstein, 1932): *B. inclinatum* × *B. caespiticium; B. carneum* × *B. atropurpureum; B. lacustre* × *B. arnellii*.

RHIZOGONIACEAE

Rhizogonium Brid.

R. dozyanum Lac.	n = 7	Kurita, 1937, 1939; Yano, 1954c
R. spiniforme (Hedw.) Bruch	n = 6	Kurita, 1937, 1939

Rhizogonium spiniforme (Hedw.) Bruch.

n = 6; Fig. 15, 16

This collection came from the base of El Yunque in northeastern Puerto Rico, and we are indebted to Carmen Rossy-Valderrama, University of Puerto Rico, for providing us with cytological material of this species. The chromosome number n = 6 agrees with previous reports for *R. spiniforme*, a pantropical species that ranges north to Georgia, Florida and Louisiana in the U. S., and throughout the world in tropical and subtropical zones. The two species investigated belong to different sections of the genus, *R. dozyanum*, with n = 7 to Section Pleuropelma while *R. spiniforme*, n = 6, has been placed in Section *Pyrrhobryum*. It should be pointed out that the 7-chromosome *R. dozyanum* is dioicous, while the 6-chromosome *R. spiniforme* is synoicous, a fact of some significance inasmuch as it does not conform to the pattern found in *Mnium:* dioicous species have monoploid gametophytes while synoicous species have diploid gametophytes.

Chromosome numbers in *Rhizogonium* are suggestive of *Mnium* and the *Mniaceae*, but chromosome behavior is quite different. Second division anaphase chromosomes in *Mnium* are invariably long and somatic-like (see Lowry, 1948), but in *Rhizogonium* the chromosomes are much condensed and not at all like somatic chromosomes (fig. 16). The late anaphase II SMC illustrated in figure 16 shows 6 chromosomes at each of the four poles.

AULACOMNIACEAE

Aulacomnium Schwaegr.

A. androgynum (Hedw.) Schwaegr.	n = 10-11	Heitz, 1945
A. palustre (Hedw.) Schwaegr.	n = 12	Steere et al., 1954
	n = (9)10	Heitz, 1928
	n = 12	Vaarama, 1950b
A. turgidum (Wahl.) Schwaegr.	n = 12	Steere, 1954

Aulacomnium heterostichum (Hedw.) BSG

n = 12; Fig. 17

This report is apparently the first record of chromosome number in this handsome and distinctive moss, a common species in Eastern North America.

Although twelve seems to be the common number of chromosomes found in the genus *Aulacomnium*, we can reasonably expect to find populations with polyploid numbers, the result of aposporic regeneration (La Rue, 1929). The other three species for which recent reports indicate the number n = 12 are all dioicous; *A. heterostichum* is autoicous so we were somewhat surprised that it did not turn out to be polyploid. Bearing green capsules at the meiotic stage in early spring, this species overwinters with the sporophyte developed to the point that it is visible to the naked eye. We investigated two populations from North Carolina, one from the Mountains and one from the Piedmont. The bivalents are of approximately the same size class, but their behavior distinguished two of them. These two bivalents divide precociously at first anaphase, one preceding the other. The meiotic configurations are without anomalies.

Aulacomnium palustre (Hedw.)

Schwaegr.

n = 12; Fig. 18

Our results confirm those of Vaarama (1950b), so we feel confident that Heitz's estimate, n = 9–10, can be dismissed as representative of an aberrant population or as an error.

This dioicous moss does not fruit commonly but we were able to obtain plants from one

population from a boggy area beneath a stand of *Pinus echinata* Mill., about 5 miles west of Durham, Durham Co., North Carolina. Many of these plants bore capsules in which meiosis was underway, and we could easily establish that *A. palustre* from North Carolina resembles the Finnish population reported by Vaarama by having the chromosome number n = 12.

BARTRAMIACEAE

Bartramia Hedw.

B. crispata Schimp.	n = 8	Yano, 1955c
B. ithyphylla Brid.	n = 12	Vaarama, 1950b; Steere, 1954; Holmen, 1958; Anderson and Crum, in press
B. pomiformis Hedw.	n = 7-8	Heitz, 1928
	n = 8	Kurita, 1937; Vaarama, 1950b; Lowry, 1954a; Steere, 1954; Yano, 1955b
var. *crispa* (Web. & Mohr.) BSG	n = 8	Vaarama, 1950b

Bartramia pomiformis Hedw.

n = 8; Fig. 19

This common moss has been studied extensively by Lowry (1954a) and Yano (1955c, 1957b). Our count is in agreement for this species, n = 8, including a precociously disjoining m-chromosome, which all investigators have reported.

Bartramia crispata and *B. pomiformis*, both with the chromosome number n = 8, belong to Section *Eubartramia*, while *B. ithyphylla* is placed in Section *Vaginella*, a large and somewhat unwieldy section with more than 80 species. The former section contains species that are strictly autoicous, with well-developed double peristome. The latter section, however, contains autoicous, paroicous and dioicous species, as well as gymostomous and variously developed peristomate species. Section *Vaginella* is delimited by the fact that the leaves are squarrose or widely spreading from a sheathing base, while members of Section *Eubartramia* have strict leaves without a differentiated base. It will be most informative to know the chromosome numbers of additional species in Section *Vaginella* to see if the present chromosome distinctions hold up.

Holmen (1958) suggests that the basic chromosome number of *Bartramia* may be 4, a hitherto unknown basic number. If the number n = 12 remains constant for Section *Vaginella*, some taxonomist will doubtless cast about for a generic segregate.

Order ISOBRYALES

PTYCHOMITRIACEAE

Ptychomitrium (Bruch) Fürnr.

Ptychomitrium drummondii Sull.

n = 13; Fig. 20, 21

The cytology of this family has not been studied previously.

Rich mats of *P. drummondii* occur on tree branches, and occasionally on rock. When wet, the mats impart a vivid green coloration. Capsules cover the mats in abundance throughout the early winter, and in early spring reach meiosis.

Ptychomitrium drummondii possesses an unusually interesting chromosome set. Of the 13 bivalents one, a precociously disjoining chromosome, is outstandingly small. Another small chromosome, but distinguishable from the smallest, can be recognized. The largest member of the complement strikes the eye not only because of its size, but also because of its tendency to dissociate after all other chromosomes have completed first anaphase (Fig. 21). We did not observe lagging to the extent that any chromatin was excluded from the interphase nuclei. Three additional chromosomes approach the largest in size, but are completely regular in that they and the 7 intermediate size bivalents disjoin simultaneously. This species promises to be a rewarding one for somatic chromosome study.

The chromosomes and their behavior do not show strong resemblances to those in any species of *Grimmia*, but remind us of the type of configurations we have found in *Orthotrichum*.

Orthotrichum Hedw.

O. alpestre Hornsch.	n = 11	Anderson and Crum, in press
O. bolanderi Sull.	n = 6	Steere et al., 1954
O. consobrinum Card.	n = 11	Yano, 1951b
O. cupulatum Brid.	n = 11	Steere, 1954
var. *nudum* (Dicks.) Braithw.	n = 11	Vaarama, 1956
O. jamesianum Sull.	n = 18	Anderson and Crum, in press
O. laevigatum Zett.	n = 6	Steere et al., 1954; Anderson and Crum, in press
O. lyellii Hook. & Tayl.	n = 6	Steere et al., 1954
O. rivulare Turn.	n = 11	Steere et al., 1954
O. roellii Vent.	n = 6	Anderson and Crum, in press
O. rupestre Schleich.	n = 6	Steere et al., 1954
O. sordidum Sull. & Lesq.	n = 6	Anderson and Crum, in press
O. speciosum Nees	n = 6	Vaarama, 1950a; Steere, 1954; Anderson and Crum, in press
O. stramineum Hornsch.	n = 13	Vaarama, 1953a

O. tenellum Bruch	n = 9	Vaarama, 1953a
	n = 10	Vaarama, 1953a; Steere et al., 1954
O. texanum Sull.	n = 6	Steere et al., 1954; Anderson and Crum, in press

Since 1950, fifteen species of *Orthotrichum* have been studied cytologically. Except for *O. tenellum* and *O. jamesianum*, all species have either 6 or 11 haploid chromosomes; to date, all with 6 chromosomes have superficial stomata and the n = 11 species have sunken stomata. Curiously enough, however, *O. jamesianum*, also with sunken stomata, has the number n = 18, which would be easier to account for in the 6-chromosome superficial stomate species.

Orthotrichum ohioense Sull. & Lesq.

n = 11; Fig. 44

This species and the next are perhaps the commonest species of this genus in Eastern North America and neither species has heretofore been studied cytologically. Both *O. ohioense* and *O. pusillum* belong to the group or subsection (according to Brotherus, 1925) "*Orthotricha staminea*", two species of which have been studied previously, *O. stramineum*, n = 11, and *O. tenellum*, n = 9, 11. Two capsules of the latter were studied by Vaarama (1953a), and in one capsule he found the number n = 9 in all of the sporocytes examined, while in the other capsule all of the SMC observed, had the number n = 11. Steere et al. (1954), however, examined a half dozen capsules from a population of *O. tenellum* obtained from the same locality, the Stanford University Campus, and uniformly the number n = 11 was observed. Vaarama's single capsule with 9 bivalents appears to have been an aberrent plant, and the observation that *O. tenellum* can exist with 9 of the usual 11 bivalents suggests that at least 2 chromosomes of the complement contain duplicate genes or else the chromosomes involved are genetically inert. There is no indication from Vaarama's account or from the drawings presented that the reduced number could have arisen by chromosome breakage and consequent translocations.

The chromosomes of *O. ohioense* conform closely in size and behavior to other 11-chromosome species of *Orthotrichum*. Ten relatively large bivalents and one tiny bivalent comprise the complement (Fig. 44). As shown in figure 44, the small bivalent dissociates prematurely in all sporocytes, a condition that has been observed in all of the other 11-chromosome species.

Orthotrichum pusillum Mitt.

n = 11; Fig. 45

We studied three populations of this common species from three scattered collections in the Piedmont of North Carolina, and in each population the number n = 11 was observed. Normally, the species is corticolous, often occurring on shade trees, especially elms, planted along city streets, college and university campuses, or around homes. One of the populations that we studied (V.S.B., Cyt. 293, Durham), however, was collected on a stone wall, which is somewhat disconcerting in view of the fact that most taxonomic keys to the species of *Orthotrichum* utilize substrate (whether corticolous or rupestral) as a major diagnostic character. The plants in this collection, incidentally, also bear abundant propagula or brood bodies, resembling those produced by *O. obtusifolium* and other species of *Orthotrichum*. The production of propagula by *O. pusillum* is not often mentioned in manuals.

The chromosomes of *O. pusillum* are very similar to those described for *O. ohioense* (cf. Figs. 44 and 45). A striking difference, however, lies in the size of the SMC in the two species; those of *O. ohioense* are nearly twice the diameter of SMC of *O. pusillum*. This size difference is curious, because the leaf cells of *O. pusillum* average considerably larger (16 μ or larger) than in *O. ohioense* (9–11 μ) (Crum and Anderson, in press). The spores of *O. ohioense* average 20 μ in diameter and only about 15 μ in *O. pusillum*.

Wettstein (1932) cites natural hybrids believed to result from crosses of four species of *Orthotrichum: O. anomalum* × *O. stramineum; O. sprucei* × *O. diaphanum*. Both alleged hybrids involve parents from different sections of the genus, and the alleged cross between *O. anomalum* and *O. stramineum* involves, respectively, a species that normally grows on rocks and one that is usually found on the bark of trees, although *O. stramineum* apparently is rarely found on rocks. Also, *O. sprucei* and *O. diaphanum* generally occupy different ecological niches, the former in rather damp places, the latter in drier areas. As with most so-called natural hybrids of mosses, these must be regarded with extreme uncertainty.

Macrocoma (Hornsch.) Grout

Macrocoma hymenostomum (Mont.) Grout

n = 12; Fig. 22

This report is the first record of chromosome number within the Macromitrioideae, an enormous assemblage of tropical and subtropical mosses, whose taxonomy is rather poorly understood, especially at the generic level. *Macrocoma hymenostomum*, known for a long time in this country as *Macromitrium sullivantii* C. Müll, is a Southern Appaiachian disjunct, restricted apparently to a small area in northern Georgia and South Carolina and southern North Carolina, confined almost entirely to the Blue Ridge Escarpment; and it is widely distributed in Mexico and in Central and South America.

The chromosome complement of *M. hymenostomum*, as in *Orthotrichum*, contains one small chromosome (Fig. 22) that disjoins prematurely. The other chromosomes in the complement can be divided into two size classes, 8 larger chromosomes and 3 smaller ones.

To what extent the large and cumbersome genus, *Macromitrium*, should be subdivided has been a matter of some uncertainty. Grout (1946) elevated *Macrocoma* to generic status and erected *Craspedophyllum*, a later homonym for which Steere (1950) has provided the name *Groutiella*. The basis for these segregates rests mainly on gametophytic characters, e.g., the shape of basal leaf cells, extent of the leaf border, etc. Chromosome studies of additional species might provide further clues as to relationships within this complex, and will be awaited with much interest.

CRYPHAEACEAE

Cryphaea Mohr.

Cryphaea glomerata Schimp.

n = 11; Fig. 23

This count is the first for the family Cryphaeaceae. The chromosomes resemble the very common 11-bivalent complement found in the majority of the members of the Isobryales. It includes the customary m-chromosome. This small and faintly staining member dissociates before the larger chromosomes, but is apparently distributed regularly through both divisions.

A closely allied species, *C. nervosa* (Hook. & Wils.) BSG, differing in general aspect of the plants, longer, more acuminate leaves, and in the fact that the costa extends almost to the apex of the leaf, often grows admixed with *C. glomerata*. We are positive, however, that the chromosome count was obtained from plants of the latter.

LEUCODONTACEAE

Leucodon Schwaegr.

L. sciuroides (Hedw.) Schwaegr. n = 11 Ho, 1956

Leucodon julaceus (Hedw.) Sull.

n = 10; Fig. 24–28

The gametophytic chromosomes of *L. sciuroides* were studied by Ho (1956). He reported the number n = 11 but his drawing shows 12 chromosomes. One large and two somewhat shorter chromosomes are distinguishable from the remaining smaller members.

The meiotic chromosome complement of *L. julaceous* is dominated by an impressively large bivalent among 9 other bivalents. The large bivalent is almost double the size of the next largest member (Fig. 24). It disjoins precociously and at early anaphase can be seen to bear two light bands midway between the almost median centromeres and the ends of the chromosomes (Fig. 25). The half-bivalents reach the poles before anaphase movement starts for the other 9 bivalents (Fig. 26), and are easily distinguished at early MII (Fig. 27) by their large size. Figure 28 shows the completion of meiosis with 10 chromosomes in each of the four sets. Chromatids of the large precociously dividing bivalent can be recognized in figure 28, showing their regular distribution to each of the four poles during AII. Note the less condensed and somatic-like nature of the large chromosome at this stage.

These two counts for *Leucodon* are the only cytological studies in the family Leucodontaceae. Throughout the suborder, Leucodontineae, only the numbers 10, 11 and 33 have been reported for the 6 species known cytologically.

Order HYPNOBRYALES

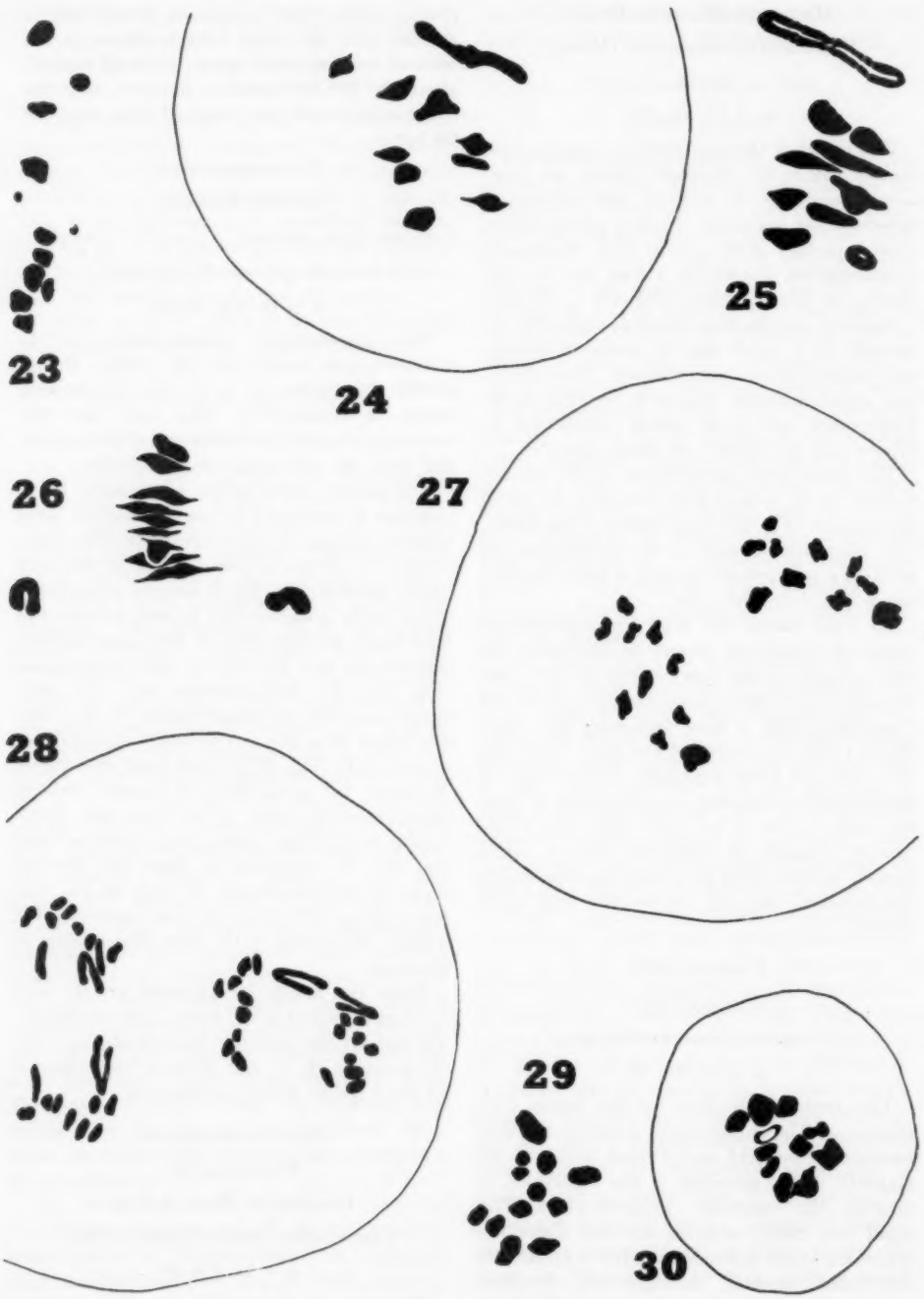
FABRONIACEAE

Clasmatodon Hook. & Wils.

Clasmatodon parvulus (Hampe.) Sull.

n = 11; Fig. 46

This report is the first for the Fabroniaceae. The chromosomes of *Clasmatodon* are remark-



FIGS. 23–30

ably uniform in size, but one member of the complement disjoins early and is in midanaphase I before the remaining bivalents begin to separate. We have made an intensive investigation of the cytology of this species and will discuss these observations in detail in a paper now in preparation.

The Fabroniaceae, as presently understood, contains a rather diverse assemblage of genera, grouped into four subfamilies in which evidence for natural groupings is not always obvious. Genera as dissimilar, e.g., as *Fabronia* and *Anacamptodon* are placed in the *Fabronioideae*; *Clasmatodon*, *Dimerodontium* and the poorly understood genus *Myrinia*, are grouped together in the Myrinioideae, all with different peristome types. The important work of Lawton (1951), who discovered that the peristome of *Clasmatodon* is actually double, rather than single, has done much to clarify the situation in this subfamily. The presence in the Helicondontioideae of genera with well-developed double peristomes and others with no peristome, costate and ecostate genera, as well as other differences, also raises doubts as to the naturalness of this subfamily. The Habrodontioideae is monogeneric, containing only *Habrodon*. Detailed chromosome studies coupled with careful peristome investigations in this family would be most profitable.

THUIDIACEAE

Thuidium BSG

T. glaucinum Bosch. & Lac.	n = 10	Sannomiya, 1957
T. japonicum Dozy. & Molk.	n = 10	Shimotomai & Koyama, 1932
T. micropteris Besch.	n = 10	Yano, 1951b
T. recognitum (Hedw.) Lindb.	n = 11	Steere, 1954
T. uliginosum Card.	n = 10	Yano, 1951b, 1952
T. viridiforme Card.	n = 10	Yano, 1951b, 1952

Thuidium delicatulum (Hedw.) Mitt.

n = 11; Fig. 30

Our meiotic studies of this species agree in number of bivalents with Steere's work on the closely related *T. recognitum*, but the chromosome sets appear to differ in some degree. In *T. delicatulum* we have found one small chromosome characterized by precocious disjunction. Its disjunction pattern too is characteristic, since the bivalent is commonly found in the form of a circle with only the ends of the half-bivalents in contact; as anaphase movement begins the cresent-shaped half-bivalents separate. Anaphase does not begin for the remaining 10 bivalents until the smallest bivalent is completely disjoined. Also we have found that three bivalents are distinguishable on the basis of larger size. Although no irregularities appear in the early stages of meiosis we found several cells at interphase which show excluded chromatin; a few chromatin bridges at first anaphase were observed. In most second telophase figures the chromosomes are very cohesive and clump to the extent that counts cannot be made.

Taxonomic distinctions between *Thuidium delicatulum* and *T. recognitum* are rather subtle, so the discovery of noticeable differences in the chromosomes of the two species is very surprising. The morphological differences between the two species, however, are clear-cut, if seemingly minor, and there are, apparently, valid habitat differences: *T. recognitum* is said to frequent substrates that are more apt to be calcareous, at least in the southeast.

Thuidium scitum (P. Beauv.) Aust.

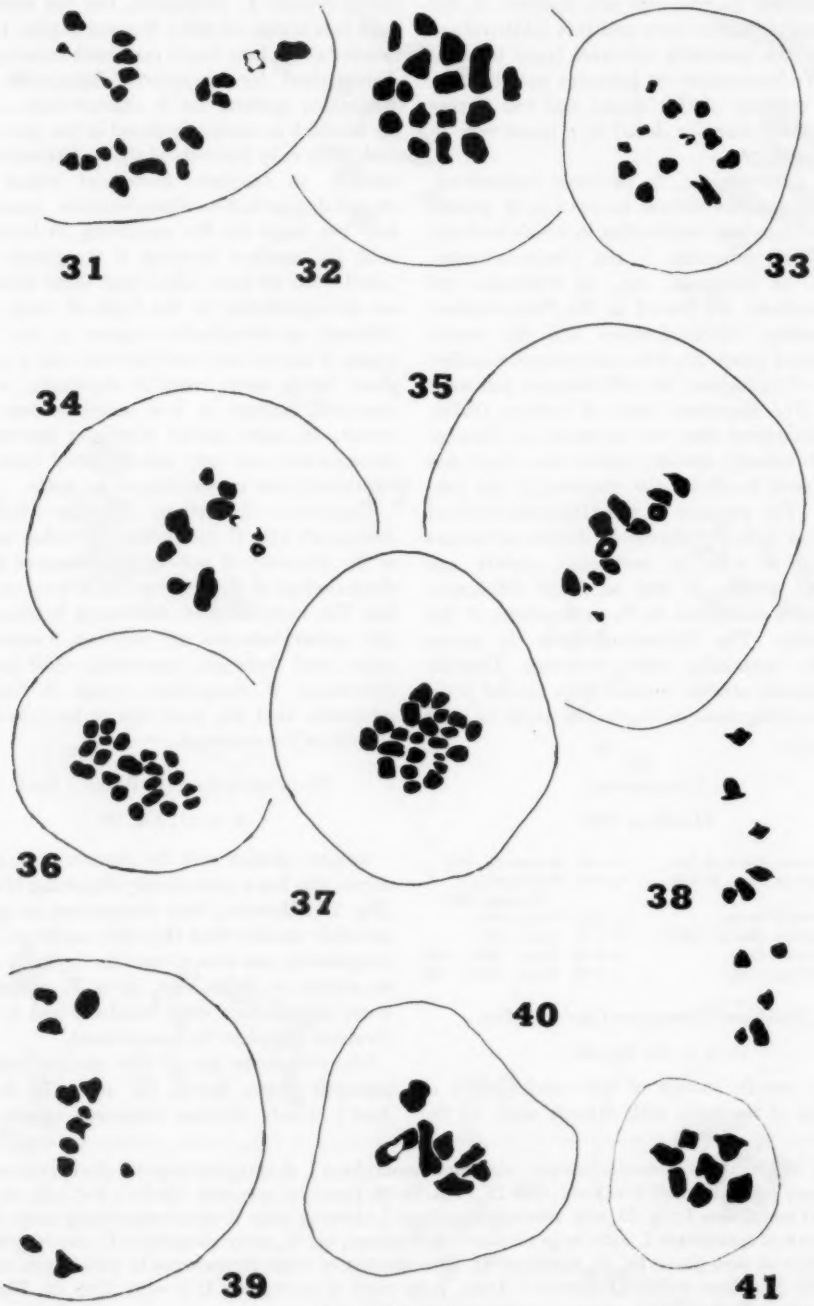
n = 11; Fig. 29

Another species with the number n = 11, *T. scitum* also has a precociously disjoining bivalent (Fig. 29). However, this chromosome is not appreciably smaller than the other members of the complement, nor does it have the typically circular pattern of disjunction. As in *T. delicatulum*, seven intermediate sized bivalents and 3 larger bivalents complete the complement.

Many authors group this species with the segregate genus *Rauia*, [*R. scita* (P. Beauv.) Aust.], which includes autoicous species with

FIG. 23, *Cryphaea glomerata* Schimp., side view, metaphase I, showing 10 large bivalents and two precociously separated half-bivalents; n = 11. FIGS. 24–28, *Leucodon julaceous* (Hedw.) Sull.; fig. 24, polar view of metaphase I; fig. 25, side view of metaphase I, showing large bivalent separating early; fig. 26, side view of metaphase I, with large bivalent in anaphase; fig. 27, early metaphase II, showing 10 half-bivalents at each plate; fig. 28, anaphase II, note identity of large chromosome in each figure; n = 10. FIG. 29, *Thuidium scitum* (P. Beauv.) Aust., polar view of metaphase I; n = 11. FIG. 30, *Thuidium delicatulum* (Hedw.) Mitt., polar view of metaphase I; n = 11.

(original magnification ×4600, reduced to ×3100)



FIGS. 31–41

branching closely once pinnate and short conic operculum. Whether *Rauia* deserves full generic status is debatable, and, as is often the case, the question is not answered by cytological characteristics. Autoicous species are also included in *Thuidium* proper (grouped into subgenus *Thuidiella*), but branching in these species is more than once pinnate and they have long rostrate opercula. Only the Japanese species, *T. micropteris*, has been studied cytologically in this group, and the number n = 10 has been reported. As noted below, however, this difference is not significant. All of the Japanese species that have been counted to date also have the same number, including *T. glaucinum*, a species belonging in the relationship that includes *T. delicatulum* and resembling it morphologically.

Including the two species of *Thuidium* reported here counts are known for three North American species and five species from Japan. The North American species, from Alaska and Eastern North America, have 11 bivalents in meiosis, while the Japanese species have one chromosome less, n = 10. Studies of North American and Japanese populations of the same species should be illuminating. The number n = 10 has been found in both dioicous species and monoicous species, as has the number n = 11. Thus *Thuidium* is another genus in which the monoicous condition is not accompanied by polyploidy.

AMBLYSTEGIACEAE

Hygroamblystegium Loeske

H. tenax (Hedw.) Jennings	n = 12	Marchal, 1912
	n = 20	Steere et al., 1954; Steere, 1954

Hygroamblystegium orthocladon (P. Beauv.) Grout

n = 20; Fig. 31

At best, *H. orthocladon* is a weak segregate of the common and ubiquitous *H. tenax* [*H. irriguum* (Wils.) Loeske]. We found the same number in *H. orthocladon* as has been reported for North American populations of *H. tenax* from California (Steere et al., l.c.) and Alaska (Steere, l.c.). Marchal's material came from Belgium, so it is possible that respective races on the two continents have uniformly different chromosome numbers.

In *H. orthocladon* we observed two small bivalents, both of which disjoin precociously. One of the two small bivalents behaves in a manner similar to that described by Bryan (1955) for *Sphagnum erythrocalyx* Hampe. The smaller of the two tiny bivalents in *H. orthocladon* dissociates in such a way that the four resulting chromatids form the corners of an open square, each being connected by fine chromatic threads (Fig. 31). The other small bivalent disjoins precociously so that by MI the half-bivalents or dyads have completely separated.

It is still not possible to postulate a basic chromosome number in any of the segregate genera of *Amblystegium*. In addition to *Hygroamblystegium*, counts have been made in *Leptodictyum*, with reports of the numbers n = 10, 24; while in *Amblystegium*, the numbers n = 12, 24, 48 were observed in the experimental series of the Marchals (1911), and in wild populations, the numbers n = 12, 13, 19, and 22 have been reported.

BRACHYTHECIACEAE

Brachythecium BSG

B. albicans (Hedw.) BSG	n = 9	Vaarama, 1950b; Ho, 1956
	n = 6	Holmen, 1958
B. Brotheri Par.	n = 11, 22	Yano, 1954a
B. buchanani (Hook.) Jaeg.	n = 10	Sannomiya, 1955
var. *japonicum* Card.	n = 10	Yano, 1954b, 1955a
B. coreanum Card.	n = 11	Yano, 1954b
B. decurrentifolium Broth.	n = 10	Yano, 1954b, 1955a
B. eustegium Besch.	n = 11	Yano, 1950, 1954b
B. glareosum (Bruch) BSG	n = 14	Steere, 1954
	n = 6	Holmen, 1958

FIG. 31, *Hygroamblystegium orthocladon* (P. Beauv.) Grout, polar view of metaphase I, showing 18 large bivalents, two half-bivalents and one m-bivalent, opened out into a quadripartite body; n = 20. FIG. 32, *Brachythecium rivulare* BSG, polar view of metaphase I; n = 16. FIG. 33, *Cirriphyllum boscii* (Schwaegr.) Grout, polar view of metaphase I; n = 12. FIG. 34, *Rhynchostegium serrulatum* (Hedw.) J. & S., polar view of metaphase I, with a tiny bivalent having disjoined precociously; n = 9. FIG. 35, *Entodon seductrix* (Hedw.) C. Müll., side view of metaphase I, with one small bivalent disjoined; n = 11. FIG. 36, *Plagiothecium denticulatum*, polar view of metaphase I; n = 20. FIG. 37, *Heterophyllium haldanianum* (Grev.) Kindb., polar view of metaphase I; n = 22. FIG. 38, *Pylaisia selwynii* (Hedw.) BSG, side view of metaphase I; n = 11. FIG. 39, *Hypnum fertile* Sendt. side view, metaphase I; n = 11. FIG. 40, *Atrichum angustatum* (Brid.) BSG, side view of metaphase I; n = 7. FIG. 41, *Pogonatum pensilvanicum* (Hedw.) Paris, polar view of metaphase I; n = 7.

(original magnification ×4600, reduced to ×3100)

B. piligerum Card.	n = 18	Yano, 1954b
B. populeum (Hedw.) BSG	n = 9, 10	Vaarama, 1950b
	n = 10	Yano, 1955a
B. rhynchostegielloides Card.	n = 10	Yano, 1957c
B. rivulare BSG	n = 6	Holmen, 1958
B. rutabulum (Hedw.) BSG	n = 11	Sinoir, 1952
	n = 5, 10	Holmen, 1958
	n = 5, 10	Moutschen, 1956
B. salebrosum (Web. & Mohr.) BSG	n = 13	Vaarama, 1950b
B. starkei (Brid.) BSG ssp. *curtum* (Lindb.) C. Jens.	n = 20	Vaarama, 1960b
B. subauriculatum Card.	n = 11	Yano, 1957c
B. tsunodae Broth. & Yas.	n = 18	Yano, 1954b
B. velutinum (Hedw.) BSG	n = 10	Marchals, 1911; Ho, 1956
	n = 11	Vaarama, 1950b

Brachythecium rivulare BSG

n = 16; Fig. 32

The 16 unusually large bivalents counted in this dioicous species constitute a chromosome number previously unreported in the genus. It differs radically from Holmen's report of n = 6 for the same species from Denmark. This species is exceedingly variable and polymorphous, it intergrades notoriously with *B. rutabulum*, and apparently only the sexual condition is completely reliable in distinguishing between the two species. Chromosome numbers in these two puzzling species may be as variable as the morphological characters, with the numbers n = 6, 16 known for *B. rivulare* and n = 5, 10, 11 known for *B. rutabulum*. Numerous varieties of both species have been described, and it is possible that some may deserve more recognition than has generally been accorded them. Of the 18 species studies cytologically more species of the subgenus Salebrosum, section Salebrosa are known than of other sections. These species, *B. tsunodae*, *B. buchanani*, *B. albicans*, *B. glareosum*, *B. piligerum*, *B. coreanum*, *B. salebrosum*, *B. eustegium*, have chromosome numbers n = 9, 10, 11, 13, 14, and 18. Numbers reported for other sections also do not agree, so as yet there appears to be no correlation of chromosome numbers and the systematic treatment of Brotherus (1925). Holmen (1958) found the number n = 6 for four species, and n = 5, 10 for one species in Denmark. In all instances, his reported numbers differ from previous reports.

Yano (1954a) considers n = 10 as the basic number. He describes the chromosomes also of three hypermonoploids which carry a small accessory heterochromosome in addition to the 10 basic chromosomes. The hypodiploid species have n = 18, the result of two sets of autosomes and only one set of heterochromosomes.

Holmen's (1958) comments on the severe cytological difficulties encountered in investigation of *Brachythecium* are pertinent, and apply not only to this difficult genus but to many other groups of mosses as well. Holmen calls attention to the puzzling situation at meiosis as follows: "The species studied here within this family Brachytheciaceae are all puzzling as regard the meiosis. At the first meiotic division the bivalents are often separating successively, and the number of 'bodies' (bivalent and precociously separated chromosomes) which can be observed at the metaphase or beginning anaphase will accordingly be varying (often from sporocyte to sporocyte). To obtain the correct chromosome number of a species, it will therefore be necessary to follow the meiosis throughout or to make controle [sic] in mitotic divisions, too." With these sentiments we are in agreement.

Cirriphyllum Grout

Cirriphyllum boscii (Schwaegr.) Grout

n = 12; Fig. 33

A genus of the Brachytheciacese previously unknown cytologically, *Cirriphyllum* is believed to include species closely related to *Eurhynchium* and to *Brachythecium*. The cytological characteristics we have observed in *C. boscii* show no marked resemblance, however, to species of *Brachythecium*. The number n = 12 is the only number in a series from 9 to 14 which has not been found in *Brachythecium*, although the number n = 6 was recently found in four species (Holmen, 1958). Comparison of figures 32 and 33 indicates the vivid differences in chromosome sizes and shapes and in sporocyte sizes between the two representatives included in this report. Chromosomes of *Cirriphyllum* are proportionately smaller and show greater variation in size. There are four small bivalents, one of which disjoins earlier than the rest. It will be very interesting, indeed, to see if these differences are apparent in other species of *Cirriphyllum*.

Rhynchostegium BSG

Rhynchostegium sp.	n = 20	Yano, 1957b

Rhynchostegium serrulatum (Hedw.) J. & S.

n = 9; Fig. 34

Nine is an uncommon chromosome number in mosses. But in this species the number was well-defined and the individual bivalents stained

deeply. Three large bivalents dominate the figures; in addition there are four medium sized and two small chromosomes. One of the small chromosomes divides into two crescent-shaped half-bivalents while the larger bivalents are still in first metaphase. The other small bivalent, also apparently has a medium centromere, but its disjunction coincides with disjunction of the larger members of the complement.

According to Yano (1957c) the chromosome set of the unidentified *Rhynchostegium* that he studied included 2 larger chromosomes and 2 m-chromosomes. The species Yano studied was monoicous, although obviously a polyploid population in view of our studies of *R. serrulatum*. In view of the great frequency of the numbers 10 and 11 in the pleurocarpous mosses it is likely that the 20 set arose from a set of 10 and the 9 set of *R. serrulatum* probably represents hypoploidy.

However, groupings at the generic level in the Brachytheciaceae are far from satisfactory. The relationships among *Rhynchostegium*, *Oxyrhynchium*, *Eurhynchium*, *Rhynchostegiella*, and *Eurhynchiella* are still not clear. In the genus *Eurhynchium*, Heitz (1928) estimated the number n = 6–8 in *E. riparioides* (Hedw.) Jennings (as *E. rusciforme*), and n = 8–9 in *E. schleicheri* (Hedw.) Lor.; while *E. substrigosum* Kindb., was found by Steere (1954) to have the number n = 10, and Lewis (1957) reported the number n = 12 for *E. confertum* (Dicks.) Milde. Holmen (1958) finds the number n = 12 in both *E. striatum* (Hedw.) Schimp. and *E. zetterstedtii* Størmer. These reports are indicative of the lack of conformity of chromosome numbers in this troublesome family.

ENTODONTACEAE

Entodon C. Müll.

E. challengeri Par.	n = 11	Sannomiya, 1955; Yano, 1955a
E. chloroticus Besch.	n = 11	Yano, 1952, 1955a
E. flaccidus Besch.	n = 11	Yano, 1952
E. ramulosus Mitt.	n = 11	Yano, 1955a

Entodon seductrix (Hedw.) C. Müll.

n = 11; Fig. 35

This common moss fruits abundantly in early winter in North Carolina. Our specimen from Durham County, North Carolina, is the first North American population studied. The four previously reported counts were from Japanese material, but the chromosomes of *E. seductrix* appear to be similar to the published chromosome drawings of the Japanese species. The conspicuous m-chromosome, a precociously disjoining bivalent, in *E. seductrix*, was also found by Yano in the species he studied. Sannomiya's drawings do not show the small chromosome in as exaggerated form as we have seen in our specimen.

The five species whose chromosome numbers are now known all belong to section Erythropus, and all are autoicous except *E. ramulosus*. Yano (1957c) compared male and female gametophytic chromosomes of this species, but could find no differences. He concluded there is no sex chromosome.

Plagiothecium BSG

P. comoriense Besch.	n = 10	Yano, 1957c
P. denticulatum (Hedw.) BSG	n = 10	Vaarama, 1950b; Yano, 1957c
	n = 11	Vaarama, 1956
	n = 25	Anderson and Crum, in press
var. *lastum* (BSG) Lindb.	n = 11	Vaarama, 1950b
P. piliferum (Sw.) BSG	n = 11	Vaarama, 1950b
P. nemorale (Mitt.) Jaeg.	n = 10	Yano, 1957c
P. rossanum (Hampe) BSG	n = 10	Yano, 1957c
P. sylvaticum (Brid.) BSG	n = 8	Yano, 1957c

Plagiothecium denticulatum (Hedw.) BSG

n = 20; Fig. 36

Apparently this monoicous species is supported by any of several chromosome numbers. In the published figures of other workers and in the many chromosome configurations we have studied of this North American population we can discern a similarity of certain members of the complement. From these similarities we believe that the basic number in the genus must be 5 so that the n = 10 species are sporophytically tetraploid, and our n = 20 species is octoploid. We believe that further studies in this polymorphic genus will turn up the numbers 15 and possibly higher multiples of 5.

It may be significant that all but one of the reports of the number n = 10 for this genus are based on somatic chromosome counts from gametophytic tissue. This suggests that the small precociously-separating bivalent observed by all investigators who have studied meiotic cells may not be evident in somatic cells, a possibility that deserves further investigation. Bryan (1955) found this to be the case in *Sphagnum tabulare* Sull., in which there are 19 large bivalents plus 2 small m-chromosomes clearly visible in SMC,

but in somatic mitoses in gametophytic tissue only 19 chromosomes were apparent. The failure of small m-type chromosomes to be evident in somatic mitoses may account for some of the discrepancies in reports of chromosome numbers in the same species. Yano has especially confined his studies to somatic chromosomes while nearly all of the other investigators who have studied moss chromosomes have worked with meiotic material.

Of considerable taxonomic interest is the fact that *P. sylvaticum* appears to have 8 chromosomes, while *P. denticulatum* populations have 10, 11, or 25. *Plagiothecium sylvaticum* is at best a very weak segregate of the extremely polymorphous *P. denticulatum*, and differs basically from the latter only in having a dioicous inflorescence, although it is usually distinguished from *P. denticulatum* by the fact that the leaves upon drying shrivel and scarcely overlap. *Plagiothecium denticulatum* is autoicous, although the antheridia are usually produced near the perichaetium, and their position probably accounts for the prolific production of capsules in this species. The dioicous *P. sylvaticum* with a lower chromosome number than in the monoicous *P. denticulatum* is larger, much more robust and produces longer stems.

SEMATOPHYLLACEAE

Heterophyllium (Schimp.) Kindb.

H. brachycarpum (Mitt.) Fleisch.	n = 11	Yano, 1950, 1951b, 1957c
H. haldanianum (Grev.) Kindb.	n = 22	Yano, 1950, 1951b, 1957c

Heterophyllium haldanianum (Grev.) Kindb.

n = 22; Fig. 37

In Nova Scotia, where our specimen was collected, this species undergoes meiosis in the late summer and early fall. The capsule at the time of meiosis has an opaque aspect, is tan in color, and the annulus is very lightly colored. These characteristics in most mosses typify the capsule in which meiosis is already completed.

Of the 22 bivalents we found, only one is noticeably smaller than the rest. It appears to have a completely regular meiotic pattern. Thus this polyploid set, although a multiple of the very common number 11, lacks the precociously-disjoining m-chromosome which so often characterizes the 11 set.

Yano (1957c) has compared the gametophytic chromosome complements in so-called antheridial and archegonial plants of *H. brachycarpum* which he describes as "dioicous" and could find no differences in the chromosomes of the two plants. In spite of this he postulates X and Y chromosomes in the two sexes on the basis of a larger heteropycnotic body in resting nuclei of antheridial plants than in archegonial plants. According to Brotherus (1925), *H. brachycarpum* is monoicous, and plants in the Duke Herbarium from Japan and so named are also monoicous. Too, this species is very similar to a North American species, *H. nemorosum* (Koch) Kindb., which is almost certainly synonymous with the Asiatic, Mexican and Central American *H. affine* (Hook.) Fleisch. The latter two are also monoicous. Possibly with further study the North American, Mexican and Central American and Japanese plants of this complex will all have to be known as *H. affine*. There is also sound phytogeographic support for such a concept.

HYPNACEAE

Pylaisia Bruch & Schimp.

P. polyantha (Hedw.) BSG	n = 11	Vaarama, 1953b; Steere 1954

Pylaisia selwynii Kindb.

n = 11; Fig. 38

Another hypnaceous genus with a chromosome set of 11, *Pylaisia* has been studied now by four cytologists. The counts represent populations from Finland, Alaska, and North Carolina. All agree on the chromosome number, and on the presence of an m-chromosome. Steere's figure 68 shows the m-chromosome in anaphase during metaphase of the remaining chromosomes. This small chromosome in our study material behaved similarly.

Pylaisia is placed in the subfamily Pylaisioideae, to which also belong two very common and widely distributed species in Eastern N. A., *Platygyrium repens* (Brid.) BSG and *Homomallium adnatum* (Hedw.) Broth. Vaarama (1953b) has studied chromosomes of *H. incurvatum* (Schrad.) Loeske and found the number n = 12, but no studies have been made of the former species.

Hypnum Hedw.

H. circinatulum Schimp.	n = 6	Yano, 1955b
H. cupressiforme Hedw.	n = 10	Vaarama, 1950b
	n = 16	Anderson and Crum, in press
H. fujiyamae (Broth.) Par.	n = 10	Yano, 1952, 1955b

H. imponens Hedw.	n = 6-7	Heitz, 1928
H. oldhami (Mitt.) Jaeg.	n = 7	Yano, 1957c
H. plumaeforme Wils.	n = 10	Yano, 1952, 1955b
H. reptile Michx.	n = 11	Yano, 1955b
H. revolutum (Mitt.) Lindb.	n = 14	Anderson and Crum, in press

Hypnum fertile Sendt.

n = 11; Fig. 39

The eight species of Hypnum whose chromosomes have been studied are mostly dioicous species. *Hypnum fertile*, as is *H. reptile*, is autoicous, and again, resembling *H. reptile*, it has a chromosome number of n = 11. The precociously dividing m-chromosome (Fig. 39) is a member of both complements. Yano has pointed out that the basic number in *Hypnum* is 6 (*H. circinatulum*) and that the number 11 as represented by *H. reptile*, is hypodiploid. According to Yano, it lacks one small heterochromatic chromosome.

In *H. fertile*, one chromosome of the complement is outstandingly large. In fig. 39, a SMC at MI, the small bivalent has already disjoined.

Mittenothamnium Hennings

Mittenothamnium diminutivum (Hampe.) E.G.B.

n = 10; Fig. 47

This Florida specimen represents the first population of the genus to be studied cytologically. *Mittenothamnium diminutivum* is a subtropical and tropical species, known from Florida, Mexico, Central America, the West Indies, and South America. In the bivalents there appears to be little size differentiation. Anaphase occurs simultaneously in all bivalents. In this family, where the number 11 is so common and where the num-

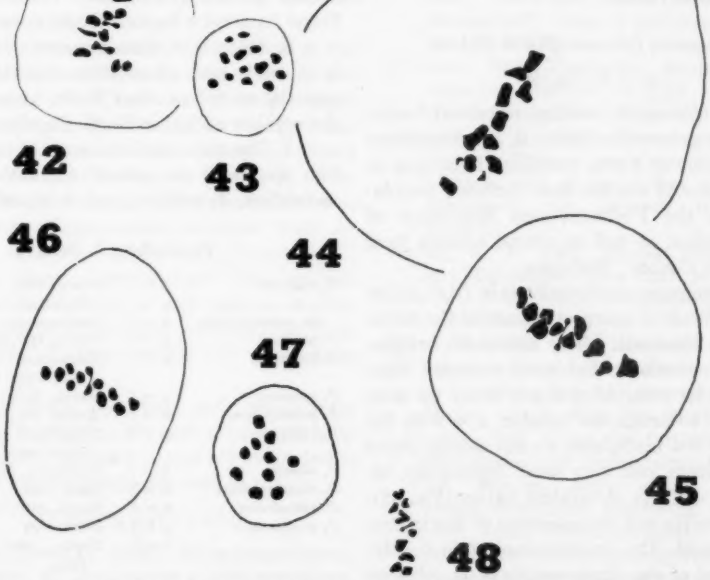


FIG. 42, *Grimmia alpicola* Hedw., side view of metaphase I; n = 14. FIG. 43, *Hyophila tortula* (Schwaegr.) Hampe, polar view of metaphase I; n = 13. FIG. 44, *Orthotrichum ohioense* Sull. & Lesq., side view of metaphase I, showing 10 larger bivalents and one small m-bivalent that has already disjoined into two half-bivalents; n = 11. FIG. 45, *Orthotrichum pusillum* Mitt., side view of metaphase I; n = 11. FIG. 46, *Clasmatodon parvulus* (Hampe) Sull., side view of metaphase I; n = 11. FIG. 47, *Mittenothamnium diminutivum* (Hampe) E. G. B., polar view of metaphase I; n = 10. FIG. 48, *Diphyscium foliosum* (Hedw.) Mohr, side view of metaphase I; n = 9.

(Figs. 42, 44, 45: original magnification ×3100, reduced to ×2900; Figs. 43, 46, 47, 48; original magnification ×2000, reduced to ×1875)

ber often includes a precociously disjoining m-chromosome, it is of interest to find the number 10 without the small chromosome.

Brotherus (1925) includes *Mittenothamnium* in subfamily Ctenidioideae. Other mosses in this subfamily whose chromosome numbers are known are *Ctenidium molluscum* (Hedw.) Mitt., n = 7 (Sinoir, 1952) 10 (Lewis, 1957); *Ptilium crista-castrensis* (Hedw.) De Not., n = 10 (Kurita, 1937; Yano, 1952, 1957c), 11 (Vaarama, 1950b; Anderson and Crum, in press), 2n = 20 (Anderson and Crum, in press). Compared with the numbers reported for other genera in the Hypnaceae there seems to be no correlation between chromosome number and this subfamily.

BUXBAUMIALES

DIPHYSCIACEAE

Diphyscium Mohr.

D. fulvifolium Mitt.	n = 9	Kurita, 1939
D. foliosum (Hedw.) Mohr as	2n = 16	Tarnavaschi, 1940–41
D. sessile (Schmid.) Lindb.		

Diphysium foliosum (Hedw.) Mohr

n = 9; Fig. 48

A moss of shaded, eroding, woodland banks, this species grows abundantly in the Mountains and Piedmont of North Carolina. Beginning in 1953 our several studies have included populations from the Piedmont and Mountains of North Carolina, as well as several colonies from Washtenaw County, Michigan.

The chromosome configurations in *Diphyscium* are very difficult to interpret because of the stickiness of the bivalents. Many chromatin bridges, lagging chromosomes, and much excluded chromatin, can be seen. After much study we were finally able to assign the number n = 9 to the species. At first metaphase we can usually count seven bivalents, one very small dissociating bivalent and one pair of bivalent halves (Fig. 48). Both sporocytes and chromosomes of this species are very small. The chromosomes stain faintly.

Our count of the chromosomes of *D. foliosum* does not agree with that published by Tarnavaschi (1940–1941) for the same species from Rumania, but coincides with the number assigned by Kurita (1939) to *D. fulvifolium*, a closely allied species from Japan. It will be of interest to study the chromosomes of *D. cumberlandianum* Harvill, an Appalachian endemic closely related to *D. involutum* Mitt., of Japan.

Order POLYTRICHALES

POLYTRICHACEAE

Atrichum P. Beauv.

A. angustatum (Brid.) BSG	n = 8	Ikeno, 1904
	n = 7	Kurita, 1937; Lowry, 1948; 1954b; Tatuno, 1951
A. crispum (James) Sull.	n = 7	Lowry, 1954b
A. giganteum (Horikawa) Wylie	n = 7	Tatuno, 1953
A. tenellum (Röhl.) BSG	n = 14	Vaarama, 1953b
A. undulatum (Hedw.) P. Beauv.	n = 16–17	Wilson, 1911
	n = 14–16	Heitz, 1926
	n = 21	Heitz, 1928; Kurita, 1937, 1939
	n = 14	Lowry, 1948, 1954b
	n = 7	Steere et al., 1954; Lowry, 1954b
A. xanthopodum (Card.) Wylie	n = 7	Yano, 1954a

Atrichum angustatum (Brid.) BSG

n = 7; Fig. 40

This conspicuous species was one of the first mosses studied cytologically. As early as 1904 Ikeno reported a haploid chromosome number of n = 8. Since that time numerous reports have been made and all of these reports for Asian material as well as other North American match the number we find in North Carolina specimens, n = 7. The same number occurs in an additional four species of the genus: *A. xanthopodum*, *A. undulatum*, *A. crispum*, and *A. giganteum*.

Pogonatum P. Beauv.

P. alpinum	n = 7	Steere, 1954; Anderson and Crum, in press
var. *septentrionale*	n = 7	Anderson and Crum, in press
P. capillare	n = 7	Kurita, 1937, 1939; Steere, 1954
P. contortum	n = 7	Shimotomai and Koyama, 1933; Yano, 1954
P. curvatum	n = 7	Kurita, 1937, 1939
P. grandifolium	n = 7	Kurita, 1937, 1938; Yano, 1954
P. inflexum	n = 7	Shimotomai and Koyama, 1932; Yano, 1954
P. nanum	n = 7	Jachimsky, 1935
P. rhopalophorum	n = 8	Ikeno, 1904
P. spinulosum	n = 7	Kurita, 1937, 1938
P. urniferum	n = 6-7	Heitz, 1928
	n = 7	Kurita, 1937, 1939; Yano, 1954a

Pogonatum pensilvanicum (Hedw.) Paris

n = 7; Fig. 41

Eleven species of *Pogonatum* have been found to have a haploid number of 7. Polyploidy has not been reported in the genus. This count is the first for *P. pensilvanicum* and in our specimen collected by Wilfred B. Schofield, in Nova Scotia,

meiosis is normal. The seven bivalents at first meiotic metaphase are relatively large and of two general size classes, four larger and three smaller chromosomes. Yano (1954a) found that the karyotypes of four species of *Pogonatum*, *P. urnigerum*, *P. contortum*, *P. grandifolium* and *P. inflexum* match the karyotypes of *Polytrichum* and *Atrichum*.

SUMMARY

1. The chromosome numbers of 38 species of mosses and one variety are recorded. Except for one species from Puerto Rico, all collections were made from Eastern North America, from Nova Scotia and Quebec to Florida. The majority of material came from the Mountains and Piedmont of North Carolina.

2. A chromosome number within Sub-class, Andreaeobrya, is reported for the first time, so that chromosome numbers are now known for representatives of all three sub-classes of mosses, Sphagneobrya, Andreaeobrya, and Eubrya. The number n = 10 was found in *Andreaea rothii* Web. & Mohr.

3. Chromosome numbers are listed in the families Ptychomitriaceae, Cryphaeaceae and Fabroniaceae for the first time. Seven previously unstudied genera, *Hyophila* Brid., *Ptychomitrium* (Bruch) Fürnr., *Macrocoma* (Hornsch.) Grout, *Cryphaea* Mohr, *Clasmatodon* Hook. & Wils., *Cirriphyllum* Grout and *Mittenothamnium* were investigated. Chromosome numbers were determined in at least one species in each.

4. The chromosome number was uniform within all populations of each species studied. No instances of intraspecific aneuploidy or polyploidy were observed within the populations studied.

5. Chromosome behavior and chromosome number is discussed under each species and in so far as possible the observations are evaluated in the light of taxonomic groupings.

LITERATURE CITED

ANDERSON, LEWIS E. 1939. The mosses of North Carolina. V. Dicranaceae to Calymperaceae. The Bryologist **42:** 62–70.

——— AND BRYAN, VIRGINIA S. 1956. A Cytotaxonomic investigation of *Fissidens cristatus* Wils. and *F. adiantoides* Hedw. in North America. Rev. Bryol. et Lichénol. **25:** 254–267.

——— AND———. 1958. Systematics of the autoicous species of *Ditrichum* subg. *Ditrichum*. Brittonia **10:** 121–137.

——— AND CRUM, HOWARD. In press. Cytotaxonomic studies of the mosses of the Canadian Rocky Mountains.

ANDREWS, A. LEROY. 1933. *Hymenostomum* in North America. V. *Weisia viridula*. The Bryologist **36:** 28–31.

BROTHERUS, V. F. 1924–1925. Musci. In A. Engler & K. Prantl, Die natüralichen Pflanzenfamilien. 2nd ed. 10–11. Wilhelm Englemann. Leipzig, Germany.

BRYAN, VIRGINIA S. 1955. Chromosome studies in the genus *Sphagnum*. The Bryologist **58:** 16–39.

———. 1956a. Cytological and taxonomic studies of some species of *Astomum*, *Acaulon* and *Phascum*. The Bryologist **59:** 118–129.

———. 1956b. Chromosomes and systematic position of the inoperculate mosses, *Pleuridium* and *Bruchia*. Amer. Jour. Bot. **43:** 460–468.

———. 1957. Cytotaxonomic studies in the Ephemeraceae and Funariaceae. The Bryologist **60:** 103–126.

CRUM, HOWARD AND LEWIS E. ANDERSON. 1956. Taxonomic studies on North American Mosses. I–V. Jour. of the Elisha Mitchell Sci. Soc. **72:** 276–291.

———. 1958. Taxonomic Studies on North American Mosses VI–XIII. Jour. of the Elisha Mitchell Soc. **74:** 31–40.

GRIESINGER, R. 1937. Über hypo- und hyperdiploide Formen von *Petunia*, *Hyoscyamus*, *Lamium* und einige andere Chromosomenzählungen. Ber. Deutsch. Bot. Ges. **55:** 556–571.

GROUT, A. J. 1904. Mosses with Hand-Lens and Microscope. New York, N. Y.

———. 1946. Orthotrichaceae. North American Flora **15A** (1): 1–62.

HEITZ, E. 1926. Der Nachweis der Chromosomen. Zeitschr. Bot. **18:** 625.

———. 1928. Das Heterochromatin der Moose. Jahrb. Wiss. Bot. **69:** 762–818.

———. 1942. Über die Beziehung zwischen Polyploidie und Gemischtgeschlechtlichkeit bei Moosen. Arch. Julius Klaus-Stift. Vererb. Sozialanth. Rassenhyg. **17:** 444–448.

———. 1945. Moosmutationen I. Spontane und durch Colchicine ausgelöste polyploide Mutanten bei *Aulacomnium androgynum*. Arch. Klaus-Stift. Vererb. Sozialanth. Rassenhyg. **20:** 119–125.

HO, PHAM HOANG. 1956. Etude de la mitose et specialement du mégachromocentre chez quelques muscinées. Rev. Gén. Bot. **63:** 1–44.

HOLMEN, K. 1955. Chromosome numbers of some species of Sphagnum. Bot. Tidsskr. **52:** 37–42.

———. 1958. Cytotaxonomical studies in some Danish mosses. Bot. Tidsskr. **54:** 23–43.

IKENO, S. 1904. Blepharoplasten in Pflanzenreich. Biol. Zentr. **24:** 211–221.

JACHIMSKY, H. 1935. Beitrag zur Kenntnis von Geschlechtschromosomen und Heterochromatin bei Moosen. Jahrb. Wiss. Bot. **81:** 203–238.

KURITA, M. 1937. Geschlechtschromosomen und Chromosomenzahlen bei einigen Laubmoosen. Zeitschr. f. Indukt. Abst.-Vererb. 24–29.

———. 1939. Chromosomen bei einigen Laubmoosen. Bot. und Zool. **7:** 385–388.

LA RUE, C. D. 1929. Regeneration in some American mosses. Pap. Mich. Acad. **11:** 225–241.

LAWTON, ELVA. 1951. The peristome of *Clasmatodon parvulus* (Hampe) Sull. Bull. Torrey Bot. Club **78:** 206–210.

LEWIS, R. L. 1957. Squash techniques in the cytological investigation of mosses. Trans. Brit. Bryol. Soc. **3:** 279–284.

LOWRY, R. J. 1948. A cytotaxonomic study of the genus *Mnium*. Mem. Torrey Bot. Club **20**(2): 1–42.

———. 1954a. The chromosome number and chromosome morphology of *Bartramia pomiformis*. The Bryologist **57:** 1–5.

———. 1954b. Chromosome numbers and relationships in the genus *Atrichum* in North America. Amer. Jour. Bot. **41:** 410–414.

MARCHAL, EM. 1912. Recherches cytologiques sur le genre "*Amblystegium*." Bull. Soc. Bot. Belg. **51:** 189–200.

———. 1920. Recherches sur les variations numériques des chromosomes dans la série végétable. Mém. Acad. R. Belg. Cl. Sci., Ser. 2, **4:** 3–108.

——— et EL. MARCHAL. 1911. Aposporie et sexualité chez les mousses. III. Bull. Acad. Belg. Cl. Sci. 1911, 750–778.

MOUNTSCHEN, J. 1956. Sur un curieux mutant de *Brachythecium rutabulum* Schpr. Rev. Bryol. Lichén. N. S. **25:** 124–127.

SANNOMIYA, M. 1955. Chromosome studies of mosses. I. Jour. of the Hattori Bot. Lab., No. 15: 114–118.

———. 1957. Chromosome studies of mosses. II. Jour. Hattori Bot. Lab. No. 18, 98–101.

SAYRE, GENEVA. 1952. Key to the species of *Grimmia* in North America. The Bryologist **55:** 251–259.

SHARP, A. J. 1955. Factors in the distribution of *Hyophila tortula* and an extension of its known range to include Michigan. Mitt. Thüring. Bot. Gesell. **1**(2/3): 222–224.

SHIMOTOMAI, N. AND Y. KOYAMA. 1932. Geschlechtschromosomen bei *Pogonatum inflexum* Lindb. und chromosomenzahlen bei einigen anderen Laubmoosen. Jour. Sci. Hiroshima Univ. B 2, **1:** 95–101.

SINOIR, Y. 1952. Génétique et cytotaxonomie des bryophytes. Rev. Bryol. et. Lichén. **21:** 32–45.

STEERE, W. C. 1938. *Barbula*. in Grout, A. J., Moss Flora of North America. **1**(3): 173–185.

———. 1950. *Groutiella*. In Crum, H., & W. C. Steere, Additions to the moss flora of Panama. The Bryologist **53:** 139–152.

———. 1954. Chromosome number and behavior in arctic mosses. Bot. Gaz. **116:** 93–133.

———, L. E. ANDERSON, AND VIRGINIA S. BRYAN. 1954. Chromosome studies on California mosses. Mem. Torrey Bot. Club **20**(4): 1–75.

TARNAVASCHI, I. T. 1940–1941. Zur Karyologie der Buxbauminales und Sporenentwicklung von *Buxbaumia aphylla* L. Bull. Sect. Scient. Acad. Roum. **23:** 383–394.

TATUNO, S. 1951. Ueber die chromosomen der Laubmoose, mit besonderer Rücksicht auf ihre Heterochromosomen. I. La Kromosome **8:** 305–310.

———. 1953. Geschlectschromosomen und Polyploidie von *Catharinaea*. Bot. Mag. Tokyo **66**(779–780): 150–154.

VAARAMA, A. 1949. Meiosis in moss-species of the family Grimmiaceae. Portug. Acta Biol. (A). R. B. Goldschmidt Vol. **1949:** 47–78.

———. 1950a. Accessory isochromosomes in the moss species *Dicranum majus*. Nature **165:** 894.

———. 1950b. Studies on chromosome numbers and certain meiotic features of several Finnish moss species. Bot. Notiser **1950:** 239–256.

———. 1953a. Chromosome fragmentation and accessory chromosomes in *Orthotrichum tenellum*. Hereditas **39:** 305–316.

———. 1953b. Some chromosome numbers of Californian and Finnish moss species. The Bryologist **56:** 169–177.

———. 1956. A contribution to the cytology of some mosses of the British Isles. The Irish Nat. Journ. **12:** 1–11.

WETTSTEIN, F. v. 1924a. Morphologie und Physiologie des Formwechsels der Moose auf genetischer Grundlage. Zeits. Indukt. Abst. Vererb. **33:** 253–257.

———. 1924b. Kreuzungsversuche Mit Multiploiden Moosrassen. Biol. Zentralbl. **44:** 145–168.

———. 1932. Genetik. *In* Verdoorn, F., Manual of Bryology. The Hague, Holland.

———. 1937. Experimentelle Untersuchungen

zum Artbildungsproblem. Zeits. Indukt. Abst. Vererb. **74:** 34–53.

——— AND J. STRAUB. 1942. Experimentelle Untersuchungen zum Artbildungsproblem. III. Weitere Beobachtungen an polyploiden *Bryum*-sippe. Zeits. indukt. Abstamm.-u. Vererb. **80:** 270–280.

WILSON, M. 1911. Spermatogenesis in the Bryophyta. Ann. Bot. **25:** 415–457.

YANO, K. 1950. On chromosomes in some mosses. Bot. Mag. Tokyo **63:** 224–225. (Abs.)

———. 1951a. On the polyploidy in two genera of moss. Jap. Jour. Genetics **26:** 229 (Abs.).

———. 1951b. On the chromosomes in some mosses. I. Bot. Mag. Tokyo **64:** 234–237.

———. 1952. On the chromosomes in some mosses. II. Bot. Mag. Tokyo **65:** 195–198.

———. 1953a. On the chromosomes in some mosses. III. Bot. Mag. Tokyo **66**(775–776): 43–38.

———. 1953b. On the chromosomes in some mosses. IV. Sex chromosomes and polyploidy of *Polytrichum*. Bot. Mag. Tokyo **66**(781–782): 197–202.

———. 1954a. On the chromosomes in some mosses. V. The karyotypes and sex-chromosomes in some species of *Polytrichaceae*. Bot. Mag. Tokyo **67**(787–788): 43–48.

———. 1954b. On the chromosomes in some mosses. VI. On the chromosomes of Brachythecium. Bot. Mag. Tokyo **67**(791–792): 129–133.

———. 1954c. On the chromosomes in some mosses. VII. Chromosomes in two genera of Polytrichaceae and other eight genera. Bot. Mag. Tokyo **67**(795–796): 243–246.

———. 1955a. On the chromosomes in some mosses. VIII. Chromosomes and sex-differentiation of *Entodon* and other two genera. Bot. Mag. Tokyo **68:** 155–159.

———. 1955b. On the chromosomes in some mosses. IX. Karyotype, sex chromosome and polyploidy of genus *Hypnum*. Bot. Mag. Tokyo **68:** 195–199.

———. 1955c. On the chromosomes in some mosses. X. Karyotype and sex chromosomes of *Bartramiaceae*. Bot. Mag. Tokyo **68:** 216–220.

———. 1956. On the chromosomes in some mosses. XI. Chromosomes in Bryaceae mosses. Bot. Mag. Tokyo **69:** 156–161.

———. 1957a. On the chromosomes in some mosses. XII. The karyotypes of genus *Plagiothecium* and other 19 genera. Jap. Jour. Genetics **32:** 67–72.

———. 1957b. Cytological studies on Japanese mosses. I. Fissidentales, Dicranales Grimmiales, Eubryales. The Kyoidu-Kagaku (Mem. Faculty of Education, Niigata Univ.) **6:** 1–31.

———. 1957c. Cytological studies on Japanese mosses. II. Hypnobryales. Mem. Takada Branch, Niigata Univ. No. 1: 85–127.

———. 1957d. Cytological studies on Japanese mosses. III. Isobryales, Polytrichinales. Mem. Takada Branch, Niigata Univ. No. 1: 129–159.

NOTES ON THE FLORA OF ROWAN COUNTY, NORTH CAROLINA

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The state of North Carolina includes three distinct provinces—the Mountain, the Piedmont, and the Coastal Plain—which are quite different floristically. Teachers and students of plant taxonomy have long delighted in this variety, and have engaged in studies designed to discover and explain the differences and similarities which exist in the three regions. In these studies considerably more attention has been devoted to the mountains and coastal plain than to the Piedmont Province. It would be reasonable to suppose that the Piedmont would have received more attention, simply because most of the major colleges and universities of North Carolina are in the Piedmont region. Perhaps many plant taxonomists in North Carolina feel that to get really interesting plant species, they must go to the mountains or to the coastal plain. This reflects the thinking of most of the plant taxonomists who have visited the state. A statistical study would probably show that the Piedmont flora contains a smaller number of rare plants than do the floras of the mountains and coastal plain, but many unusual and interesting species do occur in the Piedmont, although the number of individual plants representing each rare species is low. This opinion is held by the writer as a result of work on the spring and fall vascular flora of Rowan County, North Carolina.

This study, which included field work and a review of the pertinent literature, was begun in the fall of 1956, and continued through the spring of 1958. Collections made by those working on the Flora of the Carolinas project at the University of North Carolina strengthened the feeling that the Piedmont flora was not as well known as had been assumed. Annotated lists of unusual and interesting plants collected in the county are included in this paper. It is hoped that these lists will encourage future work in the Piedmont Province, and that they may prove useful to teachers of botany or biology in and near Rowan County.

Bounded on the west by Iredell County, the north and east by Davie and Davidson Counties, and on the south by Stanly and Cabarrus Counties, Rowan is near the center of the North Carolina portion of the Piedmont Plateau. True to the geographical position of the county, Rowan's topography is typical of piedmont regions. The hills are low and rolling. The intervening valleys and swales were formed by streams which have cut flood plains of varying widths. The majority of the streams empty into the South Yadkin and Yadkin Rivers at the northeastern border of the county. The southwestern corner of the county (less than one-ninth of the total area) is in the Rocky River drainage basin. The two highest hills in the county are Youngs Mountain, 1047 feet above sea level, and Dunns Mountain, slightly over 1000 feet above sea level (U. S. Geological Survey Map, AMS Series V501 NI 17-2).

Dunns Mountain is at the northeastern end of a granite ridge which extends in a southwesterly direction into Cabarrus County. The towns of Granite Quarry, Faith, and Shupings Mill are on this ridge. Scattered flat granite outcrops occur between Dunns Mountain and Shupings Mill. The exposed stone is relatively fault-free, and is, therefore, prized as building and monumental stone (Watson and Laney, 1906). Most of the exposed granite has been or is being quarried. Parallel to and about seven miles east of this granite ridge is a long fault separating the Carboniferous granite of the county from the Carolina Slate Belt. The underlying rocks of the slate belt are volcanic in origin and probably date from the Ordovician Period of the Paleozoic Era (Stuckey and Steel, 1953). No distinct difference in the floras of the slate and granite regions was noticed by the writer, but a more intensive study of particular species would

[1] This paper was written from data collected for a thesis submitted to the faculty of the University of North Carolina in partial fulfillment of the requirements for the Master of Arts degree in the Department of Botany. Dr. A. E. Radford suggested the problem and guided the study. Mr. Harry Ahles helped with many phases of the work. I wish to extend to both men my sincere appreciation.

probably reveal some correlation between distribution and geology.

It seems likely that M. A. Curtis and C. W. Hyams based their botanical observations, in part, on Rowan County material, but the first definite record of botanical activity in the county is a paper published by A. A. Heller in 1891. Heller had come south to collect in the mountains of the state, and visited friends in Rowan County before and after the mountain trip. Although he remained in the county over a month, his condensed report of plants encountered lists only fifty-eight Rowan County species (Heller, 1891). Heller returned to Rowan County the following year, this time in the company of J. K. Small. The two men were primarily interested in the mountain flora, but they spent a total of eleven days in Rowan County, and went on at least two collecting trips. In their published list of North Carolina plants, Small and Heller report one hundred and thirty-five species from Rowan County (Small and Heller, 1892–1893).

The early workers were followed much later by men who collected particular taxa in the county. These men include D. S. Correll (1937), H. L. Blomquist and D. S. Correll (1940), H. N. Moldenke (1945), R. K. Godfrey (1948), C. L. Rodgers (1950), and R. L. Wilbur (1955). More recently, general collections have been made in Rowan County by Dr. A. E. Radford, and Mr. H. E. Ahles.

The plant communities of Rowan County are typical of those found throughout the Piedmont. The roadsides and waste places, particularly the railroad yards, support a characteristic weedy flora. The pine forests are composed of a mixture of scrub pine and short leaf pine. These trees are quite abundant because of the number of cultivated areas which have been abandoned in comparatively recent years. Where the rivers and major streams of the county have cut wide flood plains, an alluvial forest usually develops. These woods are dominated by river birch, *Betula nigra*. The sub-canopy of the alluvial forest varies considerably from location to location. On the narrow flood plain of the South Yadkin River near US 601, for example, the Carolina silverbell, *Halesia carolina*, is an abundant understory plant. In other locations *Robinia pseudoacacia*, or *Ilex opaca*, or a mixture of many species may be found in the sub-canopy. Frequently the flood plains are bordered by steep bluffs. Where these bluffs face north or northeast, as they frequently do along the South Yadkin and Yadkin Rivers, a *Kalmia* community may develop. Where the bluffs are less steep than those supporting *Kalmia*, an oak-beech forest usually develops. While beech is the characteristic tree of these areas, it is rarely the dominant one, since various lowland oak species usually outnumber it. The climax community of the county is the oak forest. Dry areas (usually uplands) are dominated by rock chestnut oak, *Quercus prinus*; moist areas (usually lowlands), by white oak, *Quercus alba*. Both these communities have been called the oak-hickory forest by some taxonomists and ecologists, the pine-oak-hickory forest by others. In Rowan County, if not throughout the Piedmont, the writer feels that both these names are misleading. Pine is not a permanent part of the climax community of the county. Its presence in many of the oak woods there merely reflects the comparative youth of these hardwood stands. Hickory is not abundant enough to be included in the community name.

The granite outcrops of the county support those xeric communities so characteristic of granite outcrops in the southeast. Plants of many aggressive species were collected by the writer along the edges of these outcrops. This suggests that the outcrop edges are little different from other waste places, offering relatively competition-free habitats for weeds.

Plants which are endemic to or largely restricted to granite outcrops are listed below with full collection data, including the writer's collection number, in italics. The families are listed here, and in the general lists which follow, in phylogenetic order as interpreted by Fernald (1950). The genera are arranged alphabetically under the families; the species, alphabetically under the genera. Specimens of all plants listed in the paper have been deposited in the herbarium of the University of North Carolina.

ISOËTACEAE

Isoetes melanopoda Gay & Dur. Shallow stream on granite, Bringle Ferry Rd., 0.3 mi. ese. of Dunns Mtn. Rd. junct.; *645*. In a pool on granite, 0.4 mi. sw. of Shupings Mill; *826*.

POLYPODIACEAE

Cheilanthes lanosa (Michx.) D. C. Eat. On granite, Dunns Mtn., 4.0 mi. se. of Salisbury; *804*.

CYPERACEAE

Cyperus inflexus Muhl. Pool on granite, Dunns Mtn., 4.0 mi. se. of Salisbury; *553*.

PORTULACACEAE

Talinum teretifolium Pursh On granite, 0.7 mi. ssw. of Faith, *880*. On granite, 4.3 mi. wnw. of Craven, 3.3 mi. nne. of Granite Quarry; *1408*.

CARYOPHYLLACEAE

Arenaria brevifolia Nutt. On granite, 4.6 mi. wnw. of Craven, 2.8 mi. se. of intersection Long St. and Bringle Ferry Rd., Spencer; *683*.

Arenaria groenlandica (Retz.) Spreng. var. **glabra** (Michx.) Fern. On granite, Dunns Mtn., 4.0 mi. se. of Salisbury; *799*.

PAPAVERACEAE

Corydalis sempervirens (L.) Pers. Thin soil on granite, 1.5 mi. ssw. of Granite Quarry; *790*.

CRASSULACEAE

Diamorpha cymosa (Nutt.) Britt. On granite, 1.5 mi. ssw. of Granite Quarry; *816*.

EUPHORBIACEAE

Crotonopsis elliptica Willd. Near a pool on granite, Dunns Mtn., 4.0 mi. se. of Salisbury; *1442*.

SCROPHULARIACEAE

Lindernia monticola Muhl. Thin soil on granite, Rock Grove Church, 1.1 mi. sw. of Shupings Mill; *1461*.

COMPOSITAE

Senecio tomentosus Michx. On granite near a pool, 0.4 mi. sw. of Shupings Mill; *823*.

Dentaria multifida Muhl. (which appears in the general list of rare or interesting species below preceded by a daggar) is believed to be a state record, since it is not cited for North Carolina by Montgomery (1955). Of this species Montgomery says, "Its area of greatest frequency is Tennessee, northern Georgia and southern Alabama." His distribution map shows two stations in Indiana, three in Kentucky, eight in Tennessee, three in Georgia, and two in Alabama. The writer's specimens of *Dentaria multifida* are not the first from North Carolina, three other stations being known. This is, however, the first report of the species from North Carolina.

The plants of the following list are arranged as were those of the preceding one. Those species marked with an asterisk are thought to be county records, and are included in this list rather than the final one because it was felt that they were unusual enough to warrant the inclusion of habitat and collection data. A plant which appears to be a new variety of *Viola rostrata* Pursh, and an undescribed hybrid involving *Aster grandiflorus* L. are not listed here because the work on them has not been completed.

LYCOPODIACEAE

* **Lycopodium complanatum** L. Pine forest, 3.6 mi. w. of Craven, 4.8 mi. n. of Rockwell; *1466*.

* **Lycopodium lucidulum** Michx. Dry oak woods, south bank of the Yadkin River, east of US 29 bridge; *634*.

OPHIOGLOSSACEAE

* **Botrychium dissectum** Spreng. Oak woods, south bank of the Yadkin River, east of US 29 bridge; *481*.

* **Ophioglossum vulgatum** L. Alluvial woods, south bank of the Yadkin River, west of NC 49 bridge; *1036*.

POLYPODIACEAE

* **Dennstaedtia punctilobula** (Michx.) Moore Oak woods, south bank of the Yadkin River, east of US 29 bridge; *486*.

GRAMINEAE

* **Arthraxon hispidus** (Thunb.) Makino var. **cryptatherus** (Hack.) Houda Roadside, Dunns Mtn., 4.0 mi. se. of Salisbury; *558*.

Bromus tectorum L. Railroad yard, Salisbury Railroad Depot; *1224*.

* **Eulalia viminea** (Trin.) Ktze. Roadside, sw. of US 601 bridge across the South Yadkin River; *604*.

* **Gymnopogon brevifolius** Trin. Disturbed woods, south bank of the Yadkin River, east of US 29 bridge; *534*.

Panicum capillare L. Dry oak woods, where US 601 crosses the South Yadkin River; *441*.

* **Phragmites communis** Trin. Between highway and railroad embarkments, south bank of the Yadkin River, east of US 29 bridge; *494*. Rowan was the second North Carolina county in which this species was found.

CYPERACEAE

Carex oxylepis Torr. & Hook. On alluvium, south bank of the Yadkin River, west of NC 49 bridge; *1154*.

LILIACEAE

Amianthium muscaetoxicum (Walt.) Gray Stream bank in oak woods, 0.9 mi. ssw. of Granite Quarry on the road to Faith; *1458*.

Smilax tamnifolia Michx. Low oak woods, near a bridge over the backwaters of High Rock Lake, 2.6 mi. nw. of Craven, 5.3 mi. ne. of Granite Quarry; *1104*.

FAGACEAE

Quercus palustris Muenchh. Low pasture, east of US 601 bridge across the South Yadkin River, *628*.

ARISTOLOCHIACEAE

Asarum canadense L. On alluvium, South Yadkin River about 0.7 mi. upstream from the point at which it flows into the Yadkin River; *935*. On alluvium, South Yadkin River about 2.8 mi. downstream from NC 801 bridge; *987*.

CARYOPHYLLACEAE

Lychnis coronaria (L.) Desr. Fallow field, 5.4 mi. wnw. of China Grove, 4.0 mi. nnw. of Enochville; *1389*.

RANUNCULACEAE

* **Anemone caroliniana** Walt. On granite, Dunns Mtn., 4.0 mi. se. of Salisbury; *791*. Rowan is one of three North Carolina counties from which this species is known.

CRUCIFERAE

† **Dentaria multifida** Muhl. Alluvial woods, south bank of the Yadkin River, west of NC 49 bridge; *1039*, *1470*. This species is not cited for North Carolina by Montgomery (1955), and is assumed to be new for the state (see above).

ROSACEAE

Gillenia trifoliata (L.) Moench Bluff, oak woods, South Yadkin River just downstream from the mouth of North Second Creek; *955*. This plant appears to be rare in the mountains of North Carolina as well as in the Piedmont (A. E. Radford, oral communication).

Physocarpus opulifolius (L.) Maxim. Alluvial woods, south bank of the Yadkin River, west of NC 49 bridge; *1159*.

* **Prunus umbellata** Ell. Upland pine-oak woods, southwest of US 601 bridge across the South Yadkin River; *657*. Holmes (1918) reported this species for Anson, Montgomery, Richmond, and Stanly Counties, the first report of the plant in North Carolina. This collection extends the range of the species but slightly.

LEGUMINOSAE

Vicia grandiflora Scop. Roadside, 2.4 mi. n. of Franklin, 1.7 mi. sse. of US 601 bridge across the South Yadkin River; *679*.

EUPHORBIACEAE

Acalypha virginica L. Roadside, where US 601 crosses the South Yadkin River; *438*. Although this plant is listed as a common one by Blomquist and Oosting (1953), it is included because of its peculiar distribution pattern. It occurs in the Piedmont of northern South Carolina and southern North Carolina, and in two counties in extreme western North Carolina. Most of the material previously treated as *Acalypha virginica* L. is actually *A. rhomboidea* Raf. (H. E. Ahles, oral communication).

PYROLACEAE

Monotropa hypopithys L. Low oak woods, 3.0 mi. ne. of Gold Hill, 3.4 mi. se. of Liberty; *1372*.

ERICACEAE

Leucothoë axillaris (Lam.) D. Don Alluvial woods, South Yadkin River, about 0.5 mi. upstream from US 601 bridge; *976*.

Leucothoë editorum Fern. & Schub. Wooded riverbank, near a bridge crossing the South Yadkin River 5.3 mi. sw. of Mocksville, 5.0 mi. nw. of Woodleaf; *425*. Alluvial woods, South Yadkin River, about 2.8 mi. downstream from NC 801 bridge; *982*. The two species above are quite difficult to separate. The first is generally thought to be a coastal plain plant; the second, a mountain plant. The occurrence of both in a middle Piedmont county is interesting.

PRIMULACEAE

Lysimachia hybrida Michx. Wet meadow, 3.5 mi. ese. of Gold Hill, 6.4 mi. ssw. of Pooltown; *1418*.

STYRACACEAE

Halesia carolina L. Roadside, sw. of US 601 bridge across the South Yadkin River; *654*.

CONVOLVULACEAE

Convolvulus spithamaeus L. Railroad embankment, 1.2 mi. se. of Gold Hill on US 52; *1056*.

SCROPHULARIACEAE

Gratiola viscidula Pennell Low wet spot in a pasture, east of US 601 bridge across the South Yadkin River; *621*.

CAPRIFOLIACEAE

Viburnum nudum L. Low wet meadow with *Rubus*, 0.6 mi. se. of US 601 bridge across the South Yadkin River; *1230*.

COMPOSITAE

Centaurea maculosa Lam. Roadside, 2.8 mi. w. of Landis, 1.1 mi. n. of Enochville; *1387*.

Cirsium carolinianum (Walt.) Fern. & Schub. Roadside, 3.6 mi. w. of Craven, 5.8 mi. n. of Rockwell; *1272*.

Cirsium muticum Michx. Low woods, near a bridge crossing the South Yadkin River 5.3 mi. sw. of Mocksville, 5.0 mi. nw. of Woodleaf; *421*.

Erigeron philadelphicus L. Railroad yards, Salisbury Railroad Depot, *1211*.

Helenium brevifolium (Nutt.) Gray On alluvium, south bank of the Yadkin River, west of NC 49 bridge; *1150*.

* **Tragopogon major** Jacq. Roadside, US 601 bridge across the South Yadkin River; *1235*. This species was reported for the first time for North Carolina by Ahles, Bell, and Radford (1958) as *Tragopogon dubius* Scop. The Rowan County material was not included in that report.

The preceding list includes several rare plants considered to be county records. Species in the following list are quite common and are to be expected in Rowan County. The general ranges given for these species by monographers and those who have worked out the county-by-county distribution of certain taxa in North Carolina, include Rowan County in most, if not all, instances. The species are listed here as county records because no citation of them for Rowan County could be found in Batson (1952), Blomquist (1948, 1955, 1957), Blomquist and Correll (1940), Cappel (1954), Correll (1937), Godfrey (1948, 1950), Holmes (1918), or Rodgers (1950).

Botrychium virginianum (L.) Sw.
Osmunda cinnamomea L.
Osmunda regalis L. var. *spectabilis* (Willd.) Gray
Adiantum pedatum L.
Dryopteris hexagonoptera (Michx.) Christens.
Woodsia obtusa (Spreng.) Torr.
Woodwardia areolata (L.) Moore
Agrostis hyemalis (Walt.) BSP.
Agrostis perennans (Walt.) Tuckerm.
Alopecurus carolinianus Walt.
Andropogon glomeratus (Walt.) BSP.
Andropogon scoparius Michx.
Andropogon ternarius Michx.
Anthoxanthum odoratum L.
Aristida dichotoma Michx.
Aristida longespica Poir.
Aristida longespica Poir. var. *geniculata* (Raf.) Fern.
Aristida oligantha Michx.
Bromus secalinus L.
Cynodon dactylon (L.) Pers.
Dactylis glomerata L.
Echinochloa crusgalli (L.) Beauv.
Eleusine indica (L.) Gaertn.
Eragrostis hirsuta (Michx.) Nees
Erianthus alopecuroides (L.) Ell.
Erianthus contortus Ell.
Erianthus giganteus (Walt.) Muhl.
Festuca elatior L.
Gymnopogon ambiguus (Michx.) BSP.
Holcus lanatus L.
Hystrix patula Moench
Leptoloma cognatum (Schultes) Chase
Lolium multiflorum Lam.
Melica mutica Walt.
Muhlenbergia capillaris (Lam.) Trin.
Muhlenbergia schreberi J. F. Gmel.
Panicum ashei (Pearson) Fern.
Panicum dichotomiflorum Michx.
Paspalum dilatatum Poir.
Paspalum longipilum Nash.
Poa annua L.
Poa cuspidata Nutt.
Poa pratensis L.
Poa trivialis L.
Sorgum halepense (L.) Pers.
Sphenopholis nitida (Biehler) Scribn.
Sphenopholis obtusata (Michx.) Scribn.
Sporobolus clandestinus (Biehler) Hitchc.
Stipa avenacea L.
Uniola latifolia Michx.

Scirpus cyperinus (L.) Kunth
Xyris torta Sm.
Juncus biflorus Ell.
Juncus coriaceus Mackenz.
Juncus scirpoides Lam.
Aplectrum hyemale (Muhl.) Torr.
Corallorhiza odontorhiza (Willd.) Nutt.
Goodyera pubescens (Willd.) R. Br.
Habenaria clavellata (Michx.) Spreng.
Asarum virginicum L.
Chaerophyllum tainturieri Hook.
Cicuta maculata L.
Cryptotaenia canadensis (L.) DC.
Osmorhiza longistylis (Torr.) DC.
Thaspium barbinode (Michx.) Nutt.
Gnaphalium calviceps Fern.
Gnaphalium peregrinum Fern.
Liatris squarrosa (L.) Michx.

SUMMARY

The location, topography and drainage, geology, and botanical history of Rowan County, North Carolina, are discussed briefly. The various plant communities found in the county are discussed in terms of their dominants. An annotated list of Rowan County plant species which are endemic to granite outcrops, or largely restricted to such outcrops, is included. Interesting species other than these are listed separately. A third list contains common plant species reported for the first time for Rowan County. These lists are offered in support of the writer's opinion that the flora of the North Carolina Piedmont Plateau is not as well known as many workers have assumed, and is, indeed, worthy of further investigation.

LITERATURE CITED

AHLES, H. E., C. R. BELL, AND A. E. RADFORD. 1958. Species new to the flora of North or South Carolina. Rhodora **60**: 10–32.

BATSON, W. T., JR. 1952. The rushes of North and South Carolina. Jour. Elisha Mitch. Sci. Soc. **68**: 93–104.

BLOMQUIST, H. L. 1948. The Grasses of North Carolina. Duke University Press, Durham, N. C.

———. 1955. The genus *Xyris* L. in North Carolina. Jour. Elisha Mitch. Sci. Soc. **71**: 35–46.

———. 1957. A revision of *Hexastylis* of North America. Brittonia **8**: 255–281.

——— AND D. S. CORRELL. 1940. A county check list of North Carolina ferns and fern allies. Jour. Elisha Mitch. Sci. Soc. **56**: 63–105.

———. AND H. J. OOSTING. 1953. A Guide to the Spring and Early Summer Flora of the Piedmont, North Carolina, 5th ed. Published by the authors, Durham, N. C.

CAPPELL, DAN E. 1954. The genus *Scirpus* in North Carolina. Jour. Elisha Mitch. Sci. Soc. **70**: 75–91.

CORRELL, D. S. 1937. The orchids of North Carolina. Jour. Elisha Mitch. Sci. Soc. **53**: 139–171.

FERNALD, M. L. 1950. Gray's Manual of Botany, 8th ed. American Book Co., New York, N. Y.

HELLER, A. A. 1891. Notes on the flora of North Carolina. Bull. Torr. Bot. Club **18**: 186–192.

GODFREY, R. K. 1948. Studies in the Compositae of North Carolina, I. *Liatris*. Jour. Elisha Mitch. Sci. Soc. **64**: 241–249.

———. 1950. Studies in the Compositae of North Carolina, II. An enumeration of noteworthy distribution records. Jour. Elisha Mitch. Sci. Soc. **66**: 186–194.

HOLMES, J. S. 1918. Extension of the range of *Prunus umbellata* into North Carolina. Jour. Elisha Mitch. Sci. Soc. **34**: 126–129.

MONTGOMERY, F. H. 1955. Preliminary studies in the genus *Dentaria* in eastern North America. Rhodora **57**: 161–173.

MOLDENKE, H. N. 1945. The known geographical distribution of members of the Verbeniaceae and Avicenniaceae, supplement 3. Castanea **10**: 35–46.

RODGERS, C. L. 1950. The Umbelliferae of North Carolina and their distribution in the southeast. Jour. Elisha Mitch. Sci. Soc. **66**: 186–266.

SMALL, J. K. 1933. Manual of the Southeastern Flora. The Science Press Printing Co., Lancaster, Pa.

——— AND A. A. HELLER. 1892–1893. Flora of western North Carolina and contiguous territory. Mem. Torr. Bot. Club **3**: 1–39.

STUCKEY, J. L. AND W. G. STEEL. 1953. Geology and mineral resources of North Carolina. Educational Series No. 3. North Carolina Department of Conservation and Development, Raleigh, N. C.

U. S. Geological Survey Map. AMS Series V501. NI 17-2. Charlotte Quadrangle. Printed by Army Map Service, Corps of Engineers, 12–54, 9126.

WATSON, T. L. AND F. B. LANEY. 1906. The building and ornamental stones of North Carolina. North Carolina Geological Survey Bulletin No. 2. E. M. Uzzell, Public Printer, Raleigh, N. C.

WILBUR, R. L. 1955. A revision of the North American genus *Sabatia* (Gentianaceae). Rhodora **57**: 1–33, 43–71, 78–103.

JOURNAL

OF THE

Elisha Mitchell Scientific Society

VOLUME 74
1958

This Society was founded in 1883 through the efforts of
Francis Preston Venable

Published for the Society
by the
University of North Carolina Press

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(5) BRAUER, A., AND N. MACON. Amer. Jour. Math. **71**: 349–361. 1949.
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FERNALD, M. L. 1950. Gray's Manual of Botany, 8th ed. American Book Company.

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